Pressure Ulcers in Trauma patients with Preventive Spinal Immobilization

Incidence, characteristics and risk factors

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Proefschrift

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Content

Chapter 1

General background and outline of the thesis

Wietske H.W. Ham

Introduction

History of trauma

'Trauma' is defined as 'injuries to human tissue and organs, resulting from energy imparted from the environment. These injuries are caused by any form of energy beyond the tolerance level of the human body' (1).

Ironically, the essentials of the current trauma care are based on the promising results of military care and treatment of the wounded soldiers from wars during the first decades of the 20th century (2). Since the publication of the report on 'accidental death and disability' in 1966, (3) the world gradually started to recognize traumatic injury as a serious threat to the global health. This report provoked the first official steps in the introduction of a worldwide trauma system, in order to improve the quality of trauma care. The trauma system involved registration of data and the implementation of a systematic and uniform approach to evaluate and treat trauma patients. The system covered the complete chain of trauma care: paramedics, emergency department, trauma care and rehabilitation (4). Data registration provided insight in the epidemiology and served as a basis for prevention programs. In 1979 the first Advanced Trauma Life Support (ATLS) course for physicians was introduced. This course teaches a systematic and concise approach for the immediate management of the trauma patient (2). The essentials of the course were translated to paramedic and nursing care; in 1984 the first Prehospital Trauma Life Support (PHTLS) course was introduced to paramedics, and in 1986 the first Trauma Nursing Core Course (TNCC) was introduced for emergency nurses (5). Since the introduction of a trauma system, retrospective studies indicated a decrease of preventable mortality and increase of quality of care in trauma patients (4,6-9).

Preventive spinal immobilization

The PHTLS, the ATLS and TNCC are internationally recognized training programs, which educate a systematic and uniform assessment, evaluation, and treatment of trauma patients from the scene of accident to the emergency department. After a trauma accident, the first caregivers to evaluate trauma patients are paramedics following the PHTLS program. The trauma patient will be presented to the emergency department if further evaluation of the suspected or found injuries is necessary. After arrival in the emergency department, a trauma team will immediately assess, evaluate and treat the trauma patient following the ATLS and TNCC program.

One of the important objectives of these programs is to prevent spinal *cord* injury as a result of displacement of spinal fractures due to movement. Spinal cord injury involves lesions of the spinal cord or segmental nerves that affect the neural conduction of

sensory and motor signals. It is invalidating, as it will lead to a partial or complete paralysis (9). Spinal cord injury results in disability, and an increase of healthcare costs. Spinal cord injured people may experience several healthcare problems like depression, pain, urinary and sexual dysfunction, depression, and pressure ulcers (10-18).

The rationale for the prevention of spinal cord injury is to stabilize the spine and prevent movement, by immobilization. Immobilization can be achieved manually (temporary) or by the application of immobilizing devices (prolonged).

Therefore, from the scene of accident, all trauma patients with suspected spinal injury are immobilized with an extrication backboard, an extrication collar, combined with headblocks (19,20). The backboard should only be used as an extrication device, and should be removed as soon as possible after patient presentation in the Emergency Department (19,21,22). It is a rigid board that produces succinct pressure on the skin. Time on the backboard should be minimalized, as the succinct pressure may eventually lead to pressure ulcer development (23-26). Spinal immobilization is continued without backboard, but by straight alignment of the spine and supine body position. The extrication collar combined with headblocks remain in place until spinal injury is diagnosed or excluded.

Pressure ulcer risk

Although the (possible) injured spine is protected, the application of immobilizing devices may increase the risk for pressure ulcer development. Immobility in particular, is a known major risk factor for pressure ulcer development. The definition of pressure ulcer is 'localized injury to the skin and/or underlying tissue, usually over a bony prominence, resulting from sustained pressure (including pressure associated with shear)'. (27,28). Pressure ulcer development should be prevented, as they are a major physical, financial and mental burden to patients and their relatives. Pressure ulcers greatly affect the quality of life, morbidity, mortality, and rehabilitation (29-32).

This specific group of trauma patients with suspected spinal (cord) injury, may have a particular risk for developing pressure ulcers. The pressure ulcer risk is already present at the scene of accident, where immobility starts, since they are immobilized with a backboard, extrication collar and headblocks. The risk remains in case of diagnosed spinal injury, requiring immobilization. If however, spinal injury is ruled out, further injuries can lead to prolonged periods of immobilization. Fractures of large bones like pelvis, or femora, or fractures of the costal bones are illustrative for injuries that postpone or hinder mobilization. Next to immobility, trauma patients are presumably exposed to other risk factors for pressure ulcer development. First, their injuries may lead to decreased sensation; direct tissue damage; decreased dermal perfusion due to hypovolemic shock; altered nutrition; and surgical interventions. All of these conditions are known to increase pressure ulcer risk (33). Second, the PU risk may also

increase due to the fact that trauma patients are regularly exposed to devices, which increases PU risk (27,34). Immobilizing devices are used as prevention (extrication collar, blackboard, headblocks) or treatment (casts, external fixation), and medical devices are used to monitor or manage the patients' condition (endotracheal tubes, oxygen masks, nasogastric tubes, urinary tubes or restraints).

General aim of the thesis

This thesis focuses primarily on the development of pressure ulcers in trauma patients with suspected spinal injury. Our study population involves trauma patients with suspected spinal injury, immobilized with a backboard, cervical collar and headblocks by paramedics. Our studies focuses on two phases. The first is the acute phase, which includes period from the scene of accident, evaluation in the emergency department, until exclusion or diagnosis of spinal injury. During this phase, trauma patients remain immobilized for preventive reasons. After this phase, immobilization for preventive reasons ends, but continues in case of diagnosed injury. This is referred to as the second phase, the follow-up phase. This phase includes evaluation and treatment during hospital admission.

The following general research questions serve as the fundament for our studies:

- What is the incidence of pressure ulcers in trauma patients, immobilized with a backboard, extrication collar and headblocks due to suspected spinal injury?
- What risk factors play a role in pressure ulcer development in trauma patients with suspected spinal injury?

Outline of the thesis

In **chapter 2**, we systematically review the literature regarding pressure ulcers related to spinal immobilization with devices in adult trauma patients. In this review we included studies that described the occurrence and severity of pressure ulcers, the risk factors for pressure ulcers and the possible interventions to prevent pressure ulcers. Studies were included if participants were healthy volunteers under spinal immobilization or trauma patients admitted to the hospital under spinal immobilization until spine injuries were diagnosed. In **chapter 3** we assess the pressure ulcer identification and classification skills of emergency nurses and emergency physicians. Furthermore, the short-term effect of an educational intervention is evaluated. Pressure ulcers are identified and classified using photographs of normal skin, blanchable erythema, and wounds matching each pressure ulcer severity category. Emergency nurses and physicians are trained to apply the transparent-disk method, to differentiate between blanchable redness and category 1 pressure ulcers. The identification and classification skills are used for data collection in the study as described in **chapter 4.** In this chapter, we focus on the acute phase.

All included trauma patients are admitted to the emergency department with suspected spinal cord injury. First, we describe the incidence of pressure ulcers, indentation marks and pain from the extrication collar and headblocks. Second, we explore the influence of risk factors for the development of pressure ulcers, indentation marks and pain. **Chapter 5** describes a discussion paper, in reaction to the introduction of the new version of the prehospital spinal immobilization guidelines in the Netherlands, in 2014. This paper discusses the type of revisions, the (lack of) scientific evidence and the implications for practice. With this paper, we hope to initiate a discussion in order to support the development of safe and reliable trauma care throughout the entire chain of care. **Chapter 6** focuses on the follow-up phase. The incidence and characteristics of pressure ulcers in trauma patients with suspected spinal injury, admitted to the hospital after evaluation in the emergency department is described. In the follow-up phase, immobilization for preventive reasons has ended, but continues in case of diagnosed injury. We specifically highlight the description of the incidence and characteristics of device-related pressure ulcers. In **Chapter 7**, we subsequently explore the influence of risk factors for pressure ulcer development in these trauma patients. We specifically focus on risk factors already present at the emergency department, in order to identify patients at risk in an early stage. In **Chapter 8** we describe the general discussion of this dissertation. We present an outline of the current evidence regarding pressure ulcer development in trauma patients with suspected spinal cord injury. We focus on the development of pressure ulcers as an unintended adverse effect of spinal immobilization in the acute phase, and the risk of pressure ulcer development in this specific group of patients in the follow-up phase, with an emphasis on device-related pressure ulcers. Based on this overview we describe recommendations for further research and nursing practice.

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Chapter 2

Pressure ulcers from spinal immobilization in trauma patients: A systematic review

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Abstract

Background

To protect the (possibly) injured spine, trauma patients are immobilized on backboard or vacuum mattress, with a cervical collar, lateral headblocks, and straps. Several studies identified pressure ulcer (PU) development from these devices. The aim of this literature study was to gain insight into the occurrence and development of PUs, the risk factors, and the possible interventions to prevent PUs related to spinal immobilization with devices in adult trauma patients.

Methods

We systematically searched PubMed (MEDLINE), EMBASE, Cochrane, and CINAHL for the period 1970 to September 2011. Studies were included if participants were healthy volunteers under spinal immobilization or trauma patients under spinal immobilization until spine injuries were diagnosed or excluded. Outcomes of primary interest included occurrence, severity, and risk for PU development as well as prevention of PU development related to spinal immobilization devices.

Results

The results of included studies show an incidence of collar-related PUs ranging from 6.8% to 38%. Described locations are the occiput, chin, shoulders, and back. The severity of these PUs varies between Stages 1 and 3, and one study describes PUs requiring surgical debridement, indicating a Stage 4 PU. Described risk factors for PU development are high pressure and pain from immobilizing devices, the length of time in/on a device, intensive care unit admission, high Injury Severity Scores (ISS), mechanical ventilation, and intracranial pressure monitoring. Preventive interventions for collar-related PUs include early replacement of the extrication collar and regular skin assessment, collar refit, and position change.

Conclusion

The results from this systematic review show that immobilization with devices increases the risk for PU development. This risk is demonstrated in nine experimental studies with healthy volunteers and in four clinical studies.

Introduction

Trauma is defined as injuries to human tissue and organs, resulting from energy imparted from the environment. These injuries are caused by any form of energy beyond the tolerance level of the human body (1). Trauma can be intended or unintended and caused by traffic accidents, sport injuries, burns, falls, violent acts, or drowning. Although most of the developed countries established a trauma registry plan, an overview of worldwide trauma figures is difficult because of the absence of or incomplete and varying trauma registry processes (2,3). In the United States, 2.1 million trauma patients are admitted to the hospital annually (4). In the Netherlands, more than 71,336 trauma patients were hospitalized in 2011 (5). In most Western countries, trauma patients who require medical help in the emergency department (ED) are assessed, treated and evaluated following the guidelines of the Advanced Trauma Life Support. These guidelines prescribe to immobilize the spinal cord with appropriate spinal immobilization devices, to protect the (possible) injured spine (6). Commonly used devices are a backboard or vacuum mattress, cervical collar (C-collar), as well as lateral headblocks and straps. Backboards prevent spinal movement and are used by paramedics to extricate the patient from the scene of accident and to transfer the patient to the ED. C-collars prevent movement of the cervical spine (C-spine). To further protect the C-spine from movement; the C-collar is often combined with lateral headblocks and straps. Patients wear these C-collars until C-spine injury is ruled out or diagnosed, which requires radiologic tests and clinical examination of the C-spine (7). Awaiting radiology can extend periods of C-spine immobilization. The backboard should be removed as soon as possible after patient presentation in the ED, (6,8-10) but this is not common practice in every ED. As a result, patients are immobilized with the backboard for extended periods awaiting evaluation and radiology tests to rule out spinal injury (11,12). Although immobilization devices are applied to protect the spine, several studies identified negative effects of spinal immobilization in trauma patients. One of these negative effects is the development of pressure ulcers (PUs) (8,13) caused by prolonged immobilization with backboards and C-collars. The international definition of a PU is as follows: ''Localized injury to the skin and/or underlying tissue usually over a bony prominence, as a result of pressure in combination with shear.'' (14).

PU-related pain and discomfort have great impact on the quality of life. In addition, PUs affect physical, social, psychological, and financial aspects of the quality of life and impair rehabilitation (15,16). Next to the impact on patients, PUs have a financial impact on health care. The exact financial impact is difficult to calculate, although Bennett et al. (17) (2004) calculated treatment costs for each PU stage, which begins with E1.06 or $1.947 (Stage 1) and may increase to a maximum of E24,214 or $44,312 (Stage 4, if complicated with osteomyelitis). In the most recent study in the Netherlands, PU-

related health care costs are estimated at 1.21% to 1.41% of the total costs of health care (18). During the last years, the health care supply industry developed a wide range of immobilization devices. Costs, constructions, and materials of these immobilizing devices vary widely. The choice and application of the devices depend on a hospital's policy. At present, several studies have investigated the risk for PU development caused by spinal immobilization. These studies focus on risk factors for immobilizing device related PU in trauma patients as well as tissue interface pressures (TIPs) caused by immobilizing devices in healthy volunteers. However, no attempts have been made to systematically review the available research evidence regarding the occurrence, risk factors, and preventive interventions for PU development related to the application of different immobilizing devices. This literature study focuses on PUs, as a complication of immobilization of the spine with existing immobilizing devices. The aim of this literature study was to gain insight in the occurrence and severity of PUs, the risk factors for PUs, and the possible interventions to prevent PUs related to spinal immobilization with devices in adult trauma patients.

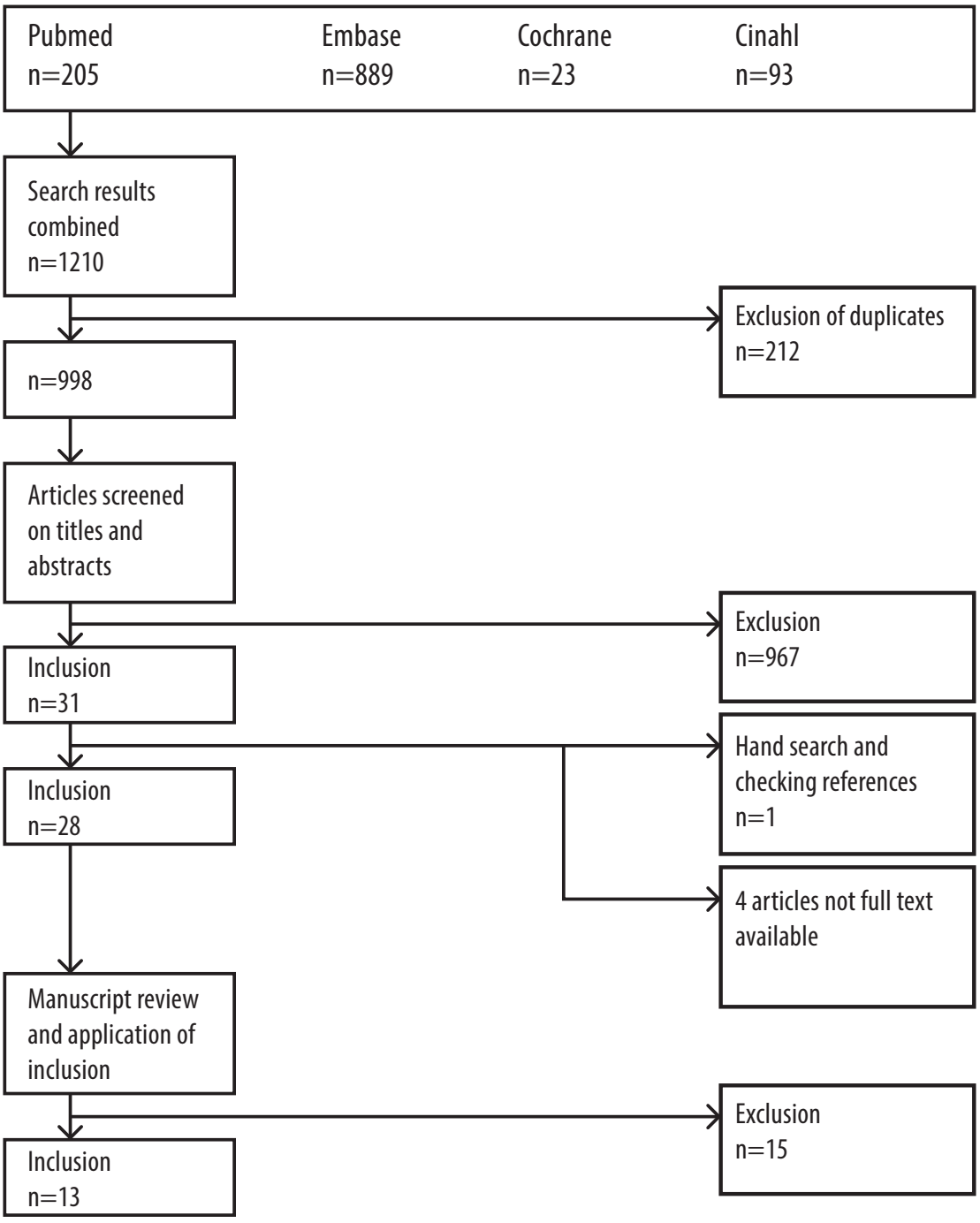
Patients and Methods

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement was used to conduct and report the review (19). A systematic search of studies listed in PubMed (MEDLINE), EMBASE, Cochrane, and CINAHL was conducted for the period 1970 to September 2011. Search strategies for each database included terms derived from our research aim (Appendix 1).

Selection Procedure and Quality Appraisal

All types of quantitative clinical designs were included. There were no restrictions in language, publication date, or publication status. Studies were included if participants were healthy volunteers under spinal immobilization or trauma patients admitted to the hospital under spinal immobilization until spine injuries were diagnosed. Outcomes of primary interest were defined as follows: spinal immobilization devices and occurrence of PUs, severity of PUs, or risk for PU development or prevention. Studies were excluded if abstracts were not available. We used the research appraisal checklist (RAC) for nursing reports to assess the quality of included studies (20). The RAC is applicable to all quantitative research reports and consists of 51 criteria, grouped into eight research categories as follows: title, abstract, problem, literature review, methodology, data analysis, discussion, form, and style. Each criterion was rated from 1, which means not met, to 6, which means fully met or not applicable (n.a.). Scores were summated for each category, and category scores were counted up to a grand total score. If one or more criteria were considered n.a., grand total scores were adjusted, as described by Duffy (20). To prevent bias, the research category ''literature review'' was considered

Figure 1. Selection procedure



n.a. for all included studies, whereas most of the medical journal guidelines in which studies were published did not require an extensive literature review in the introduction section. In four studies, criteria for instruments were n.a.; these studies did not use instruments to collect observational data (21-24). Adjusted (grand) total RAC scores were converted into percentages of maximum (adjusted) RAC scores by the reviewers for improved comparison. Scores between 0% and 33.3% were considered ''below average,'' between 33.4% and 66.7% ''average,'' and between 66.8% and 100% ''superior.'' This score classification is similar to the classification as described by Duffy (20). The selection procedure and quality appraisal were performed independently by two reviewers (W.H. and L.S.). Any disagreements were discussed and resolved by consensus.

Data Abstraction and Synthesis

Data were extracted and inserted into tables. The following data were extracted: author, year of publication, design, language, sample size, immobilization device, outcome measures, instruments, study methods, preventive interventions, and results. Meta-analysis of the results was impossible because of the wide variations in design, variables, and samples.

Results

Study Selection

The search strategy resulted in a total of 998 hits. After screening titles and abstracts using our inclusion criteria, 31 articles remained for full-text screening. Examination of reference lists revealed one additional study. Four articles were not available full text, resulting in 28 articles for fulltext screening. After reading these 28 fulltext articles in detail, 15 were rejected for the following reasons: nature of the report (case study, editorial, quality improvement project, pilot study); population under study did not match inclusion criteria; main focus on immobilization in general; and main focus on C-spine clearance. The remaining 13 studies were included. The selection procedure is presented in Figure 1.

Characteristics of Included Studies

Four non-experimental studies (21-24) and nine experimental studies (25-33) were analyzed. Their characteristics are summarized in Tables 1 and 2.

All nonexperimental studies were observational and described the incidence, risk factors, and characteristics of C-collar related PUs in trauma patients. Sample sizes varied from n = 34 to n = 484, including severely injured trauma patients (23) diagnosed with closed head Injuries (24) or with actual or suspected head or spine injuries (21,22).

Table 1. Studies with trauma patients

Author (publication year)	Design, Sample size, setting	Immobilization device	Investigated risk factors	Significant risk factors	Incidence, characteristics	Preventive intervention
Chendrasekhar et al. (1998)	Retrospective record audit n=34	Semi-rigid cervical collar	Age, gender, ISS, GCS, AIS-H, time in C-collar, overall survival.	Long C-collar application (21.5 days, sd 0.99, p=0.001)	Incidence: 38 %, 2 ulcers required surgical debridement.	no
Ackland et al. (2007)	Retrospective record audit n=299	S-C, P-C.	Demographics, mechanism of injury, GCS on admission, Length of stay in ED, ICU and wards, mechanical ventilation, time to C-spine clearance.	Time to C-spine clearance ($p \leq 0.001$), ICU admission (13% vs. 3.9%, p= 0.007), mechanical ventilation (18% vs. 4.9%, p= 0.005), ventilation time (9.4 days, sd 12.7 vs. 3.1 sd 5.8, $p \leq 0.005$), necessity for cervical MRI (27% vs. 0.9%, $p \leq 0.001$).	Incidence: 9.7 % located on occiput (59%), chin, clavicle and shoulders. 86.3 % occurred after ≥3 days, 65.5% after ≥ 6 days and 41.4% after ≥ 10 days of admission.	S-C replaced in ED for P-C. Skin inspection (and occiput) and collar refit every 4-8 hours, position change every 2-4 hours.
Powers et al. (2006)	Prospective descriptive study n=484	S-C, A-C	BMI, age, time from admission to placement in A-C, vasopressor use, appropriate fit, extend of edema, activity level, use of small back panel, length of time in c-collar, length of ICU stay.	Days in a C-collar ($p < 0.0001$), time in S-C (p?). Increase of odds ratio for collar-related PU related to days in a c-collar and edema.	Incidence: 6.8%, 5.6% stage 1 or 2 and 1.2 % stage 3, located on 5.5% shoulders, chin and back.	S-C replaced < 24 for A-C. Cleaning and assessing skin under collar every 12 hours, changing pads every 24 hours.
Molano et al. (2004)	Prospective cohort study n=92	S-C	Age, gender, ISS, ICP monitoring, days of mechanical ventilation, length of stay	High ISS scores (37.5, sd 9.8 vs. 31.2 sd 4.9 $p<0.01$), length of stay (24.6 days sd 10.9 vs. 10 sd 10.3, $p<0.01$), days of mechanical ventilation (15.4, sd 8.2 vs. 6.1 sd 9, $p<0.01$) and ICP monitoring ($p<0.01$).	Incidence: 23.9%, located at chin (36.8%), occipital (28.9%), suprascalpular (13.2%).grade 2 (42.1 %), grade 3(39.5%). Most severe lesions occipital (46.7% grade 3) and later detected (median 13 days, RI 5-19).13.2 % occurred on 2nd day, 7 th day was medium detection day (RI:5 to 13.8).	Based on results of study: multidisciplinary protocol: Optimized C-spine clearance protocol, apply suitable semi-rigid collar, skin care every 8 hours. Assessment of occipital skin area every 24 hours.

CRPU, Collar Related Pressure Ulcers; **S-C**, Stifneck® collar; **P-C**, Philadelphia collar®; **A-C**, Aspen ® collar; **ED**, Emergency department; **SD**, Standard Deviation; **R**, Range; **M**, Mean

Table 2. Experimental studies with healthy volunteers

Author, year	Type of study	Sample size	Immobilization device	Outcome	Subgroup analysis	Methods	Results
Berg et al., 2010	Experimental, randomized block design	n=73	BB	Sacral tissue oxygenation (InSpectraStO2 Tissue Oxygenation monitor)	Age, BMI, Gender	Time on device: 30 minutes	Mean tissue oxygenation measurements of sacral area before (60.3 %) and after (69.7%) were higher ($p < 0.0001$). No significant differences in sacral tissue oxygenation between ages (young < 31 yrs, older > 31 yrs.), gender and BMI groups (normal and overweight).
Edlich et al., 2011	Quasi-experimental, non-randomized, cross-over design	n= 10	Wooden BB with and without inflatable Back Raft	TIP: occiput, scapulae, sacrum (Tactilus pressure evaluator) Level of patient discomfort (VAS)	-	Time on device: 30 minutes Wash-out: 30 minutes	TIP (all areas) were higher during the period without Inflated Back Raft ($p \leq 0.05$). Highest mean TIP on backboard was 60.00 mmHg. Mean VAS scores were higher without Inflated Back Raft: 6.0 vs. 0.9 ($p \leq 0.05$). Pain levels increased after 30 minutes ($p \leq 0.05$)
Hemmes et al., 2010	Experimental randomized, cross-over design	n=30	BB, VM,SLLS	TIP: occiput, scapulae, sacrum, heels (Xsensor X2-6912) Discomfort (VAS)	-	Intervention: 15 minutes Wash-out: 5 minutes	TIP was significant higher on the BB and VM compared to SLSS in all areas ($p<0.05$). No differences in comfort between SLLS and VM, but less discomfort SLLS compared with BB ($p< 0.001$)
Keller et al., 2004	Quasi-experimental, non-randomized cross-over design	n= 20	Semi-soft overlay mattress, VM, BB.	TIP: scapulae, sacrum, heels (Xsensor X2-6912) Comfort scores (VAS)	-	Time on device: 5 minutes Wash-out: ?	TIP on the SB was highest: sacrum and scapulae were significant higher on the SB and VM ($p<0.05$). TIP on the heels were equal for the spine board and ER mattress. Volunteers appreciated overlay mattresses 7.0 (+/- 0.8) and VM 6.6 (+/- 1.3) significantly better compared to the SB(4.6 (+/-1.20) ($p<0.05$)
Cordell et al., 1995	Experimental, randomized cross-over design	n= 20	BB with and without air mattress	TIP: occiput, sacrum, heel (Talley-Scimedics Pressure evaluator MK II) Comfort (5point scale) Pain (VAS)	Age, height, weight, pound-to-inch ratio,	Time on device: 80 minutes Wash-out: 60 minutes	TIP were less on BB with air mattress, $p=0.000$. TIP did not change significant over time for both devices. Pain levels increased over time for both interventions and all locations ($P=0.001$). More pain was reported during no-mattress period ($p=0.0001$). Total pressure was related to height ($p=0.008$). There was no significant relationship between pain and pressure.

Lovell &Evans, 1994	Quasi-experimental, non-randomized cross-over design	n= 30	BB, BB with foam, VM	TIP: sacrum, mid-lumbar spine (Talley pressure sensor)	-	Time on device: 5 minutes Wash-out: 5 minutes	Differences in sacral TIP between BB with and without foam (t< 0.001, T=4.15, 29 fd) and BB and vacuum stretcher (t< 0.001, T=20.3, 29 fd). Mean sacral TIP for SB is 147.3 mmHg, for the padded board 115.5 mmHg and the VM 36.7 mmHg.
Black et al., 1998	Experimental randomized crossover design	n=20	PC, AC	TIP: occiput (Talley digital Skin pressure evaluator Model SD 500). Skin humidity and temperature (digital hygrometer sensor).	-	Time on device: 30-minute Wash-out:15 minutes	No significant difference in TIP and skin temperature between collars. Mean occipital pressures exceeded 43 mmHg for P-C and 39 mmHg for A-C. Relative skin humidity and skin temperature increased significant in both collars. Only skin humidity was significant higher with P-C (p>0,0001)
Tescher et al., 2007	Experimental. Randomized block/ cross-over design	n=48	A-C, P-C, M-C, MO-C	TIP: occiput, mandibulae (Xsensor X2 System). Cervical range of motion (cervical range of motion device).	BMI, gender	Time on device: -	All collars produced restriction of movement ($p < 0.001$). A-C produced high TIP on all locations and positions ($p < 0.001$). P-C produces highest occipital TIP (supine position). MO-C produced lowest mean occipital (supine and upright) and mandibular (supine) TIP, $p < 0.001$. Significant association between BMI and mean supine occipital TIP overall (p= 0.04)
Plaisier et al., 1994	Quasi – experimental, non-randomized cross-over design	n=20	S-C, P-C, N-C, M-C	TIP: occiput, mandibulae, chin (electro pneumatic sensor). Comfort level (5 point rating scale)	-	Time on device: -	Increase in occipital TIP between upright and supine position for S-C, P-C and N-C ($p < 0.05$). Mean pressures for M-C and N-C below 32 mmHg. S-C produced higher occipital and mandible pressures ($p<0.05$), but no significant difference in supine occipital TIP compared with P-C. Mean comfort scores of S-C (0.85) were significantly low compared to other collars (P-C 3.0, N-C 3.8, M-C 3.45), which had no significant differences in comfort.

TIP, Tissue-interface pressures; **VAS**, Visual analog Scale; **BB**, Backboard; **VM**, Vacuum Mattress; **SLLS** Soft-Layered Long Spine board; **S-C**, Stifneck® collar; **P-C**, Philadelphia ® collar; **A-C**, Aspen® collar;

M-C, Miami-J® collar; **MO-C**, Miami J® with occian back collar; **N-C**, Newport ® collar; **SD**, Standard Deviation; **R**, Range; **CI** Confidence interval

Two studies had a prospective design, (21,22) and two were retrospective (23,24). The type of C-collars that were used in the studies were extrication C-collar (Stifneck, Laerdal,Wappingers Falls, NY) (21) and long-term C-collars (Philadelphia, Philadelphia cervical collar co, NJ; Aspen, Aspen medical products, Oak Canyon Irvine, CA) (22,23). One study did not specify the type of C-collar (24). All experimental studies were performed with healthy volunteers. Six of the nine experimental studies examined the effect of different spinal immobilization devices (backboards and vacuum mattresses) on sacral tissue oxygenation, (25) Tissue interface pressure (TIP), (26-29,31) and comfort, discomfort or pain (26-29). Three of the nine experimental studies examined the effect of C-spine immobilization devices: Stifneck, Philadelphia, Aspen, Miami-J (össur, Reykjavik, Iceland), and Newport (Aspen medical products) on TIP (30,32,33) comfort, (33) range of motion, (32) skin humidity, and skin temperature (30). Sample sizes varied from n = 10 to n = 73. One study used a randomized block design, (25) and eight studies used crossover designs, (26-33) of which five used randomization (27,29,30,32). Length of time in C-spine immobilization devices or on spinal immobilization devices varied from 5 minutes to 80 minutes and was not described in two studies (32,33). Washout times varied from 5 minutes to 60 minutes and were not described in three studies (28,32,33). TIP measurements were performed with four different instruments as follows: Xsensor, (27,28,32) Tactilus pressure evaluator, (26) Talley pressure sensor, (29-31) and electro pneumatic sensor (33). Visual analog scales (VAS), 5-point Likert scales, and open interviews were used to measure comfort, discomfort, or pain.

Quality of Included Studies

The quality of included studies was either ''average'' or ''superior.'' Of the 13 included studies, seven scored 70.2% or more of the maximum grand total RAC scores, indicating superior quality; (21,23,25,27,29,30,32) the other six studies scored between 45.6% and 66.2% of the maximum total scores, indicating average quality (22,24,26,28,31,33). (Table 3) Nine studies did not perform a power calculation (22-26,28,31-33) and may have insufficient sample size to detect an effect and a risk of Type II errors. The risk for information bias is enhanced in two observational studies: one study included four investigators for data collection but did not describe the interrater reliability, (22) and one study did not provide any information of data collectors (21). Five of the experimental studies insufficiently described the reliability and validity of the applied instruments to measure TIP, which is a risk for information bias (26,28,29,31,32). Five of the eight studies with a crossover design did not describe washout times (28,32,33) or described a washout time of only 5 minutes (27,31) between treatments. Short (or no) washout times may influence the observations of the next treatment by the previous treatment with the carry-over effect.

Table 3. Quality appraisal of included studies

	Total RAC scores per category (% of maximum score*)				Adjusted total RACscores (% of maximum score*)
	Methods		Data analysis		
	Subjects	Instruments	Design		
Black et al (1998)	24/36 *(66.7%)*	12/30 *(40.0%)*	21/24 *(87.5%)*	24/24 *(100%)*	216/258 *(83.7%)*
Plaisier et al (1994)	14/36 (38.9%)	8/30 (26.7%)	11/24 (45.8%)	16/24 (66.7%)	140/270 (51.9%)
Tescher et al (2007)	22/36 (61.1%)	20/30 (66.7%)	19/24 (79.2%)	21/24 (87.5%)	193/270 (71.5%)
Berg et al (2010)	31/36 (86.1%)	15/30 (50.0%)	22/24 (91.7%)	24/24 (100%)	249/270 (92.2%)
Edlich et al (2011)	14/36 (38.9%)	9/30 (26.7%)	17/24 (70.8%)	18/24 (75.0%)	165/270 (61.1%)
Hemmes et al (2010)	27/36 (75.0%)	14/30 (46.7%)	21/24 (87.5%)	24/24 (100%)	231/270 (85.6%)
Keller et al (2005)	7/36 (19.4%)	9/30 (26.7%)	13/24 (54.2%)	11/24 (45.8%)	140/270 (51.9%)
Cordell et al (1995)	26/36 (72.2%)	10/30 (33.3%)	23/24 (95.8%)	24/24 (100%)	216/270 (80%)
Lovell et al (1994)	8/36 (22.2%)	9/30 (26.7%)	10/24 (41.7%)	10/24 (41.7%)	123/270 (45.6%)
Chendrasekhar et al (1998)	19/36 (52.8%)	5/30 (4x n.a.)	12/24 (1 x n.a.)	18/24 (75.0%)	155/234 (66.2%)
Ackland et al (2007)	29/36 (80.6%)	5/30 (4x n.a.)	13/24 (1 x n.a.)	24/24 (100%)	209/240 (87.1%)
Powers et al (2006)	26/36 (72.2%)	4/30 (4x n.a.)	11/24 (1 x n.a.)	11/24 (54.8%)	148/240 (61.7%)
Molano et al (2008)	18/36 (50.0%)	2/30 (4x n.a.)	13/24 (1 x n.a.)	20/24 (83.3%)	171/240 (70.3%)

*0%-33.3%= below average, 33.4%-66.7%=average, 66.8%-100%= superior

Occurrence and Severity of PUs

No studies that described the occurrence of PUs related to the application of spinal immobilization devices such as backboards and vacuum mattresses were found. Four of the included studies described the occurrence of PUs related to C-spine immobilization with C-collars in trauma patients. Chendrasekhar et al. (24) described an incidence of 38% in 34 trauma patients. Two of these patients needed surgical debridement, but the study did not provide further details of PU severity. Ackland et al. (23) described an incidence of 9.7% in 299 trauma patients. PUs were located at the occiput (5.7%), chin, clavicle, and shoulders. Powers et al. (22) described an incidence of 6.8% in 484 trauma patients. Of these, 6.4% were Stage 1 or 2 and 0.4% were Stage 3. PUs were located on the shoulders, chin and back (5.5%), as well as occiput (1.2%). Molano et al. (21) described an incidence of 23.9% in 92 trauma patients, admitted to the intensive care unit (ICU). The number of PUs per patient was 1.8 (0.8), and 13.2% was detected on the second admission day. PUs were located at the chin (8.8%), occiput (6.9%), and suprascalpular (3.2%). Of these, 10.1% were Stage 2 and 9.4% were Stage 3. Occipital PUs were most severe (11.2% Stage 3) and detected at a later point in time (median, 13 days; IQR, 5-19 days). (Table 1)

Risk Factors for PU Development

Chendrasekhar et al. (24), Ackland et al., (23) and Powers et al. (22) described the length of time in the C-collar as a significant risk factor for PU development. Chendrasekhar et al. (24) found that patients with PUs spent more time in a C-collar compared with patients without (21.15 ± 0.99 days vs. 4.42 ± 0.79 days, $p = 0.001$). Ackland et al. (23) described necessity for cervical magnetic resonance imaging (MRI) ($p \leq 0.001$) and time to C-spine clearance ($p \leq 0.001$) as significant predictor of PUs. In this study, the necessity for cervical MRI prolonged the length of C-collar time application. Risk for PUs increased by 66% for every day in the C-collar. Powers et al. (22) described days in a C-collar ($p < 0.0001$) and the length of time spent in a Stifneck C-collar as significant risk factors (no figures available). Powers et al. (22) described ICU admission ($p = 0.007$) and mechanical ventilation ($p = 0.005$) as significant predictors for PU development. Molano et al. (21) found that ICU patients with PUs had significantly higher ISS (mean [SD], 37.5 (9.8) vs. 31 (4.9); $p \leq 0.01$), length of stay (24.6 [10.9] days vs. 10 [10.3] days), mechanical ventilation (15.4 [8.2] days vs. 6.1 [9] days, $p \leq 0.01$) and intracranial pressure (ICP) monitoring (55.6% vs. 1.2%, $p \leq 0.01$). Black et al. (30) compared the Philadelphia and Aspen C-collar and examined the effect on skin humidity and skin temperature in healthy volunteers. They found a significant increase of skin humidity and temperature in the Philadelphia C-collar ($p \leq 0.0001$). Tescher et al. (32) compared four different C-collars in healthy volunteers and found an association between body mass index (BMI) and mean supine occipital TIP in all C-collars ($p = 0.04$). (Table 2)

Pressure and Pain from Devices

Spinal Immobilization Devices

One study (30) examined the effect of pressure from the backboard on the sacral tissue oxygenation and found significantly higher values after 30 minutes on the backboard following pressure release (p G 0.0001). TIP from the backboard on bony prominences was measured in five of the experimental studies (26-29,31). All included a backboard covered with a soft layered mattress or foam (27,31) or an interposed air mattress, (26,29) which should increase comfort and reduce TIP. Keller et al. (28) Lovell and Evans (31) and Hemmes et al. (27) additionally included the vacuum mattress. Five studies described significantly higher TIP on the backboard compared with the other immobilizing devices. (26-29,31). In two studies, (27,28) TIP was significantly higher on both the backboard and vacuum mattress compared with soft layered backboard ($p < 0.05$). Four studies described significantly more (dis)comfort and pain experienced by volunteers on the regular backboard, compared with the other devices ($p < 0.05$, $p \leq 0.05$, $p < 0.0001$, $p < 0.05$), (26-29) and a significant increase of pain was described in two studies, (26,29) after placement on an immobilizing device for 30 minutes ($p < 0.05$) and 80 minutes ($p = 0.001$). (Table 2)

Cervical Immobilization Devices

Although lateral headblocks are often used to immobilize the C-spine in the acute phase, none of the studies examined the effect of lateral headblocks on TIP. TIP from the C-collar on bony prominences was measured in three experimental studies (30,32,33). Black et al. (30) compared the Philadelphia and Aspen C-collars on the effect on occipital TIP and found no significant differences. Tescher et al. (32) compared four C-collars (Philadelphia, Aspen, and Miami-J with and without occipital padding) and compared range of motion and occipital and mandibular TIP. All C-collars produced significant restriction of movement ($p < 0.001$). The Aspen collar produced the highest TIP ($p < 0.001$), and the Miami-J collar with occipital padding produced the lowest mean occipital (supine and upright) and mandibular (supine) TIP ($p < 0.001$). Plaisier et al. (33) compared four C-collars (Stifneck, Philadelphia, Newport, and Miami-J) and examined mandibular, chin, and occipital TIP. A significant increase in occipital TIP between upright and supine position was found for all collars ($p < 0.05$), except for the Miami-J collar. The Stifneck collar produced the highest occipital and mandibular TIP ($p < 0.05$). Comfort scores (0 - 5) of the Stifneck collar (0.85) were significantly lower compared with other C-collars (3.0 - 3.45) (p value not described). (Table 2)

Interventions to Prevent PU

Three of the included studies described interventions to prevent PUs related to C-collar application, (21-23) but none studied the effect of preventive interventions on PU development. Two studies described application of preventive interventions during their study period, (22,23) which consisted of early replacement of the extrication C-collar for a long-term C-collar, skin inspection and collar refit every 4 hours to 8 hours 23 or 12 hours, 22 position change every 2 hours to 4 hours, (23) and changing pads every 24 hours (22). Based on their study results, Molano et al. (21) implemented a multidisciplinary protocol, which included an optimized C-spine clearance protocol, application of a long-term C-collar in case of prolonged cervical immobilization, and regular skin care underneath the C-collar (every 8 hours) and the occipital skin area (every 24 hours). (Table 1)

Discussion

Results of included studies show an incidence of collar related PUs, which ranges from 6.8% to 38%. Described locations are the occiput, chin, shoulders, and back. The severity of these PUs varies between Stage 1 and 3, and one study describes PUs requiring surgical debridement, indicating a Stage 4 PU. Preventive interventions for collar-related PUs are composed of early replacement of the extrication collar and regular skin assessment, collar refit, and position change. Described risk factors for PU development are high pressure and pain from immobilizing devices, the length of time in/on a device, ICU admission, high ISS, mechanical ventilation, and ICP monitoring.

Strengths and Limitations

To increase rigorousness, this systematic literature study is reported following the PRISMA guidelines. Next, the search strategy, study selection, and quality appraisal are performed by two independent reviewers (L.S. and W.H.), which enhanced validity and reliability. Study results may however have been influenced by several factors. We defined a broad literature search, to increase the number of hits. First, we did not limit our literature search on publication dates. As a result, we included five studies that were published more than 15 years ago (24,29-31,33). This will influence the quality of the study results, while newer studies may use more advanced and improved instruments or immobilizing devices. Second, we did not limit our literature search on study design. As a consequence, results from the included studies are difficult to compare because research designs, included participants, type of immobilization devices, methods, outcomes, and instruments were different. In addition, generalizability of the result from studies with healthy volunteers to the population of trauma patients is limited. The varying methodological quality between studies should be considered when interpreting study

results. Six studies had an average methodological quality caused by poorly described methods (subject selection, instruments, data analysis) (22,24,26,28,31,33). Two of the four clinical studies on PU in trauma patients were retrospective (23,24). Therefore, the incidence of PU may be lower than the true clinical picture owing to incomplete registration.

Discussion of Results

We included 13 studies, of which only four were clinical studies on C-collar related PUs in trauma patients. We did not find clinical studies that studied the risk for PU in trauma patients related to immobilizing devices such as backboards, vacuum mattresses, or C-collars combined with headblocks and straps. We also did not find studies that explored the effect of preventive interventions on PU development. Nine studies included healthy volunteers and measured effect of pressure on tissue oxygenation and TIP on bony prominences from immobilizing devices. Because we know that PUs result from pressure (and shear), (14) the risk for PU development from immobilizing devices is demonstrated in these studies by high TIPs and increased tissue oxygenation after pressure release. Immobilizing devices are used for extrication and transport and should be removed immediately after arrival in the ED (10). Time in a C-collar or on an immobilizing device should be kept as short as possible. First, pressure from these devices increases PU risk. Three clinical studies describe the length of time in the C-collar as significant risk factor for PU development and reported high to very high incidence figures (6.8-38%) (22-24). Second, changes in skin condition under the devices increase the risk for PU (14). Black et al. found an increase in humidity and temperature of the skin underneath C-collars (30). This finding is confirmed in a study on medical device related PU (34). While trauma patients are suspected for C-spine injury and thus in a C-collar, the time in a C-collar should be minimized by optimizing and standardizing the procedure for C-spine clearance. Next to length of time in a C-collar or on an immobilizing device, the severity of illness of trauma patients plays a role in PU development. We found studies that identified ''ICU admission,'' ''mechanical ventilation,'' ''high ISS,'' and ''ICP monitoring'' as significant risk factors, which implies a high severity of illness of the trauma patients. The European Pressure Ulcer Advisory Panel (EPUAP) describes factors that affect ''perfusion and oxygenation'' and the ''general health status,'' which increase the risk for PU development. (14). Nurses should be aware of the increased risk for PU development within this patient category. Pain related to pressure from the device can be a predictor for PU development. Although pain and (dis)comfort were no primary outcomes of our literature study, five studies included these outcomes related to the use of immobilizing devices in their studies with healthy volunteers (26-29,33). Pain and discomfort were significantly higher when pressures from devices were high. Next

to the increased risk of PU development, increased pain can bias clinical evaluation of the suspected C-spine, which results in prolonged immobilization with a C-collar.

The European Pressure Ulcer Advisory Panel (EPUAP) recommends evidence-based interventions to prevent PU development, such as regular skin assessment, skin care, nutritional support, frequent repositioning, and the use of pressure relieving support surfaces (14). We found three studies that described preventive interventions for C-collar related PU development that were aimed at skin assessment, skin care, and frequent positioning. Although not mentioned in the included studies, practice shows that application of some of these interventions result in labor-intensive practices not feasible in regular care. When patients are immobilized to protect the potentially injured (cervical) spine, their body is kept in supine position. The only safe way to turn a patient is by the logroll procedure to prevent (further) neurologic damage. This procedure involves turning a patient as a single unit, while maintaining straight alignment of the spine, by a minimum of four trained caretakers (6). This labor-intensive procedure and the fear of causing neurologic damage to the spine while logrolling can withhold caretakers from performing the logroll on a frequent basis. This will hinder frequent repositioning as well as regular skin assessments and skin care of the back, buttocks, occiput, and heels. In addition, immobilizing devices may hinder regular skin assessment and skin care. Optimized nutritional care may be hindered by (frequent) surgical interventions for which patients should be kept sober.

Recommendations

To gain insight in the magnitude of the problem of PU development in trauma patients, future studies should focus on PUs within the population of trauma patients and prospectively explore the relationship among immobilizing devices, patient characteristics, and PU development. In addition, possible preventive interventions for PU in trauma patients should be defined, and effectiveness should be explored. Eventually, it would be advisable to study pain (related to time in a C-collar or on an immobilizing device) as a predictor for PU development in trauma patients. In practice, nurses should be aware of the risk for PU development while in a C-collar or on an immobilizing device. Regular skin assessment and inspection underneath the device can lead to early detection of changes in skin condition. If the patient's condition permits, the evidence-based interventions as recommended by the EPUAP should be applied.

Conclusion

Results from this systematic review show that immobilization with devices increases the risk for PU development. First, this risk is demonstrated in studies with healthy volunteers by high pressures from immobilizing devices. Next, clinical studies described an increased risk for C-collar-related PUs when patients were severely ill or immobilized for prolonged period. The described incidence of C-collar related PUs varies between 6.8% and 38%, and the severity of PU ranges from stage 1 to 4. Possible preventive interventions aimed at skin assessment, skin care, and frequent positioning are described, but their effect on PU development remains unclear. This literature study reveals a need for more clinical research on PU development from immobilization devices in trauma patients and the effect of applicable preventive interventions for trauma patients.

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Appendix 1.

1. Electronic search strategy for Medline

Domain/population

1. "Wounds and injuries" [Mesh]
2. Accidents[Mesh]
3. "Cervical Vertebrae/injuries"[Mesh]
4. "Thoracic Vertebrae/injuries"[Mesh]
5. "Lumbar Vertebrae/injuries"[Mesh]
6. "Trauma Centers"[Mesh]
7. 1 OR 2 OR 3 OR 4 OR 5 OR 6
8. "multiple trauma"[tiab]
9. accidents[tiab]
10. accident[tiab]
11. injuries[tiab]
12. injury[tiab]
13. trauma patient*[tiab]
14. 8 OR 9 OR 10 OR 11 OR 12 OR 13

Intervention

15. "Equipment Design/adverse effects"[Mesh]
16. "Braces/adverse effects"[Mesh]
17. "Splints/adverse effects"[Mesh]
18. "Immobilization"[Mesh]
19. "Emergency Treatment"[Mesh]
20. immobili*[tiab]
21. collar*[tiab]
22. backboard*[tiab]
23. board*[tiab]
24. backboard*[tiab]
25. 15 OR 16 OR 17 OR 18 OR 19 OR 20 OR 21 OR 22 OR 23 OR 24
26. cervical[tiab]
27. brace*[tiab]
28. orthotic device*[tiab]
29. collar [tiab]
30. 26 AND (27 OR 28 OR 29)
31. 25 OR 30

Outcome

32. "Pressure Ulcer"[Mesh]
33. decubitus[tiab]
34. pressure ulcer*[tiab]
35. Tissue-interface pressure*[tiab]
36. pressure sore*[tiab]
37. bedsore*[tiab]

38. skin breakdown[tiab]
39. 32 OR 33 OR 34 OR 35 OR 36 OR 37 OR 38

Domain, intervention and outcome combined
40. 14 AND 31 AND 39
Hits: 205

Cinahl

(MH "Trauma+") OR (MH "Wounds and Injuries+") OR (MH "Accidents+") OR (MH "Thoracic Vertebrae/IN") OR (MH "Cervical Vertebrae/IN") OR (MH "Lumbar Vertebrae/IN") OR (MH "Trauma Centers") OR (TI "multiple trauma" OR AB "multiple trauma") OR (TI "accident*" OR AB "accident*") OR TI "Injur*" OR AB "Injur*") OR (TI "Trauma patient*" OR AB "Trauma patient*") AND (MH "Orthopedic Equipment and Supplies/AE") OR (MH "Splints/AE") OR (MH "Immobilization") OR (MH "Emergency Treatment (Non-Cinahl)") OR (TI "immobili*" OR AB "immobili*") OR (TI "collar*" OR AB "collar*") OR (TI "board*" OR AB "board*") OR (TI "backboard*" OR AB "backboard*") OR ((TI "cervical*" OR AB "cervical*"TI)AND ("brace*" OR AB "brace*") OR (TI "orthotic device*" OR AB "orthotic device*")) AND (MH "Pressure Ulcer+") OR (TI "decubitus" OR AB "decubitus") OR (TI "pressure ulcer*" OR AB "pressure ulcer*") OR (TI "tissue interface pressure*" OR AB "tissue interface pressure*") OR (TI "pressure sore*" OR AB "pressure sore*") OR (TI "bedsore*" OR AB "bedsore*") OR (TI "skin breakdown*" OR AB "skin breakdown*")
Hits: 93

Cochrane

("Wounds and Injuries"[Mesh] OR Accidents[Mesh] OR "Trauma Centers"[Mesh] OR 'multiple trauma':ti,ab OR accidents:ti,ab OR accident:ti,ab OR injuries:ti,ab OR injury:ti,ab OR 'trauma patient':ti,ab OR 'trauma patients':ti,ab) AND ("Equipment Design"[Mesh] OR "Braces"[Mesh] OR "Immobilization"[Mesh] OR "Emergency Treatment"[Mesh] OR immobili*:ti,ab OR collar*:ti,ab OR board*:ti,ab OR backboard*:ti,ab OR (cervical:ti,ab AND (brace*:ti,ab OR 'orthotic device':ti,ab OR 'orthotic devices':ti,ab))) AND ("Pressure Ulcer"[Mesh] OR Decubitus:ti,ab OR 'pressure ulcer':ti,ab OR 'pressure ulcers':ti,ab OR 'Tissue-interface pressure':ti,ab OR 'Tissue-interface pressures':ti,ab OR 'pressure sore':ti,ab OR 'pressure sores':ti,ab OR bedsore*:ti,ab OR 'skin breakdown':ti,ab)
Hits: 23

Embase

('spinal cord injury'/exp OR 'injury'/exp OR 'accident'/exp OR 'spine injury'/exp OR 'multiple trauma':ti,ab OR accidents:ti,ab OR accident:ti,ab OR injuries:ti,ab OR injury:ti,ab OR 'trauma patient':ti,ab OR 'trauma patients':ti,ab) AND ('emergency care'/exp OR 'equipment design'/exp OR 'immobilization'/exp OR 'brace'/exp OR 'orthosis'/exp OR immobili*:ti,ab OR collar*:ti,ab OR board*:ti,ab OR backboard*:ti,ab OR (cervical:ti,ab AND (brace*:ti,ab OR collar*:ti,ab OR 'orthotic device':ti,ab OR 'orthotic devices':ti,ab))) AND ('decubitus'/exp OR 'interface pressure'/exp OR Decubitus:ti,ab OR 'pressure ulcer':ti,ab OR 'pressure ulcers':ti,ab OR 'Tissue-interface pressure':ti,ab OR 'Tissue-interface pressures':ti,ab OR 'pressure sore':ti,ab OR 'pressure sores':ti,ab OR bedsore*:ti,ab OR 'skin breakdown':ti,ab)
Hits: 889

Chapter 3

Pressure Ulcer Education improves Interrater Reliability, Identification, and Classification Skills by Emergency Nurses and Physicians

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Abstract

Introduction

Pressure ulcers (PUs) are a serious health complication that develop as a result of pressure alone or pressure in combination with shearing forces. Although PUs are typically associated with older adults and chronic illness, acutely injured trauma patients may have a particular risk for the development of PUs. To prevent PU development or detect PUs in an early stage, skin assessment and PU classification should start during the Emergency Department (ED) stay, before hospital admission. The aim of this study was to assess the PU identification and classification skills of emergency nurses and emergency physicians and to evaluate the short-term effect of an educational intervention.

Methods

Twenty validated photographs were used to test identification and classification skills in a one-group pretest/posttest design, before and after an educational intervention with 54 emergency nurses and physicians. In addition, we assessed the interrater reliability of PU identification and classification.

Results

PU identification and classification skills and the multirater κ improved after the educational intervention. Accurate identification improved significantly from 87.7% to 95.6% ($P = .000$), and classification skills improved significantly from 68.5%to 79.8% ($P = .000$). The multirater κ for identification of PU increased from 0.63 to 0.82, and the multirater κ for classification of PUs rose from 0.43 to 0.58. The most frequently misclassified photographs were those that displayed category 1, 2, and 3 PUs, which were usually classified as more severe.

Discussion

This study investigated the effect of an educational intervention on the interrater reliability, PU identification, and PU classification skills of emergency nurses and physicians when tested immediately after the intervention. Study results show that interrater reliability, PU identification, and PU classification of photographs all improved, but identifying the presence of a PU in a photograph was less challenging than categorizing the same wound.

Introduction

Pressure ulcers (PUs) are a serious health complication that develop as a result of pressure alone or pressure in combination with shearing forces. PUs may be limited to the skin, to the underlying tissue, or both and are usually located over a bony prominence (1). In addition to contributing to high health care costs, PUs are a burden to patients and their family members, influencing quality of life, morbidity, mortality, and rehabilitation (2-5). Although PUs are typically associated with older adults and chronic illness, acutely injured trauma patients may be at particularly high risk for PU development. Well-established risk factors for PUs are often present in patients with multiple injuries. Traumatic injuries can lead to direct tissue damage, impaired sensation, and decreased dermal perfusion as a result of extended periods of immobilization, hypovolemic shock, and altered nutrition, which are known risk factors for PU development (1). Furthermore, trauma patients are frequently exposed to medical devices that are necessary to stabilize potential spinal injuries (eg, backboards, head blocks, and cervical collars) or immobilize fractured bones (eg, casts, splints, and external fixators). In addition to pressure and shear forces, the skin underneath these devices will be affected by humidity and heat, increasing the risk for device related PUs (6). The need for acute surgical intervention for life-threatening injuries also elevates the risk of intraoperative PU development (1,7,8). Because many trauma surgical interventions are unplanned and emergent, limited time is often available to carefully prepare and position the patient on the operating table. PU identification and classification are essential to assess severity, determine which preventive or therapeutic actions are indicated, and distinguish PUs from other types of skin lesions (eg, traumatic wounds). In injured patients, PU identification and classification are often postponed until hospital admission because they are not priority interventions. However, a baseline skin assessment and PU classification should ideally occur during the trauma patient's emergency department (ED) stay. Although PU classification and identification is a typical nursing skill, in the ED both emergency nurses and emergency physicians need to possess the requisite knowledge and skills to perform baseline PU skin assessments, because during the trauma survey, emergency nurses and physicians collaborate as one team. PU classification is difficult. Studies have shown good interrater reliability for PU experts (9) when classifying normal skin, erythema, PUs, and incontinence lesions from photographs with the European Pressure Ulcer Advisory Panel classification system, but low interrater reliability for nurses (10,11). Nevertheless, educational interventions have been shown to improve these skills. Two studies have described nurses' improved PU classification skills after an educational intervention (11,12). However, none of these studies investigated the ability of emergency nurses and physicians to identify and classify PUs. The aim of this study was to assess the PU identification and classification skills of emergency nurses

and emergency physicians and to evaluate the short-term effect of an educational intervention. PUs were identified and classified using photographs of normal skin, blanchable erythema, and wounds matching each PU severity category.

Methods

PU classification

The European and American National Pressure Ulcers Advisory Panel classification system was selected because it is the most widely used and recommended PU scoring instrument. This tool classifies PUs into 4 categories (1 to 4) based on lesion severity (1). (Table 1)

Design

A one-group pretest/posttest design was used. (Figure 1) Participants were asked to identify and classify normal skin, blanchable erythema, and wounds matching each of the 4 PU categories as illustrated in a total of 20 photographs. Photos were examined in random order, both before and immediately after an educational intervention. The intervention consisted of a 20-minute lecture in which the classification system was explained and illustrated. Participants were given a handout with descriptions and sagittal illustrations of PU wounds corresponding to the PU categories. The posttest followed immediately after the educational intervention. Participants were allowed to use the handout to assist in completion of the posttest. Data were collected between May and July 2012, during a total of 13 educational workshops. Workshops consisted of a pretest, an educational intervention, and the posttest. At the start of each workshop, the purpose and procedure were explained and subject anonymity and confidentiality were ensured. To prevent contamination, participants were instructed not to discuss the workshop. Participants were asked to switch off pagers and phones to avoid disturbances during the intervention. The Medical Ethics Review Committee of UMC Utrecht stated that the Dutch Medical Research Involving Human Subjects Acts (WMO) does not apply to this study and official IRB approval is not required under the WMO.

Sample

We did not perform a power analysis, as all nurses and physicians from the ED department were included in the study. The convenience sample (n = 54) consisted of emergency nurses and physicians (including emergency residents) from a large university medical center in The Netherlands. Although the nurses all received PU classification training as part of their nursing education, a PU classification tool or handout was not currently in use in the study emergency department.

Table 1. European Pressure Ulcer Advisory Panel Classification system[1]

Classification	Description
Category 1	Intact skin with non-blanchable redness of a localized area usually over a bony prominence. Darkly pigmented skin may not have visible blanching; its color may differ from the surrounding area. The area may be painful, firm, soft, warmer or cooler as compared to adjacent tissue.
Category 2	Partial thickness loss of dermis presenting as a shallow open ulcer with a red pink wound bed, without slough. May also present as an intact or open/ruptured serum-filled or serosanguineous filled blister. Presents as a shiny or dry shallow ulcer without slough or bruising*.
Category 3	Full thickness tissue loss. Subcutaneous fat may be visible but bone, tendon or muscles are not exposed. Slough may be present but does not obscure the depth of tissue loss. *May* include undermining and tunnelling.
Category 4	Full thickness tissue loss with exposed bone, tendon or muscle. Slough or eschar may be present. Often includes undermining and tunnelling. The bridge of the nose, ear, occiput and malleolus do not have (adipose) subcutaneous tissue and these ulcers can be shallow.

Figure 1. Pre-test post-test design

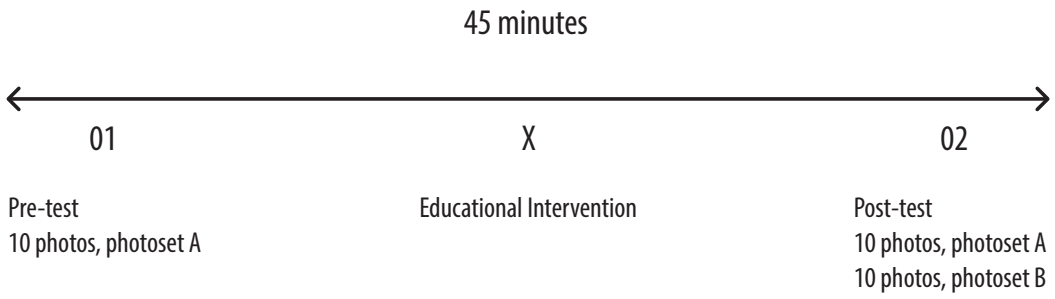


Table 2. Selected photographs

	# photographs (A)	# photographs (B)	# photographs (A+B)
all	10	10	20
Normal skin	1	2	3
Blanchable erythema	2	1	3
Category 1	2	3	5
Category 2	3	2	5
Category 3	1	1	2
Category 4	1	1	2

Educational intervention

The workshops took place in 1 of 3 ED conference rooms. During the workshop a 20-minute educational intervention was provided by a single researcher (HW). The intervention consisted of a lecture based on the Pressure Ulcer Classification (PUCLAS2) educational tool, (13) illustrated with a PowerPoint presentation (Microsoft Corporation, Redmond, WA, 2010). The presentation contained basic information and definitions, including examples and illustrations of PU causes, characteristics, and classifications.

Data collection

Baseline work experience and education information were collected from each participant. A set of 20 validated photos of normal skin, blanchable erythema, and wounds representing all 4 PU categories were chosen from the PUCLAS2 educational tool (14). The selected set consisted of 3 photos of normal skin, 3 photos of blanchable erythema, 5 photos each of category 1 and 2 PUs, and 2 photos each of category 3 and 4 PUs. PUs that develop during an ED stay are typically category 1 or 2, (14) and thus the number of category 1 and 2 photos used was deliberately higher than the number of category 3 and 4 photos used. The photographs were divided into 2 sets (photosets A and B; see Table 2). For the pretest, participants identified and classified 10 randomly presented photographs (photoset A). Photos were displayed onto a 100-inch projection screen. During the posttest, participants identified and classified 20 randomly presented photographs (photosets A + B). At the end of the workshop, participants received feedback regarding their assessment accuracy.

Data analysis

The data were used to assess PU identification and classification skills. PU identification required distinguishing PUs from normal skin and from blanchable erythema based on photographs. PU classification skills required correct classification of normal skin, blanchable erythema, and PU categories based on photographs. To evaluate the effect of PU education, the Student t test for paired groups was used. Identification and classification skills were defined as a percentage of correct ratings. The multirater Kappa (k) coefficient was calculated to evaluate the interrater reliability of identification and classification skills between raters (emergency nurses and physicians). The κ coefficient measures the proportion of agreement between raters, while correcting for chance. The multirater κ was computed in the Statistical Package for the Social Sciences macro instruction Mkappasc. This macro performs the multiraterκ statistic as described by Siegel and Castellan (15). The following criteria for the multirater κ statistic were used for interpretation of results: < 0 = poor, 0 to 0.20 = slight, 0.21 to 0.40 = fair, 0.41 to 0.60 = moderate, 0.61 to 0.80 =substantial, and 0.81 to 1.00 = almost perfect agreement between raters (16). Data were analyzed using IBM SPSS

Table 3. Description of participants

	ED nurses	ED physicians
n (%)	41(75.9)	13 (24.1)
Registered nurse	41	-
Additional Licenses		-
Emergency care	41	-
Critical care	20	-
Prehospital care	6	
Physicians	-	13
Residents	-	11
Emergency care physicians	-	2
Years of experience		
Health care (SD)	20.0 (9.7)	3.3 (1.8)
Within specialism (SD)	10.3 (7.4)	3.3 (1.9)

Statistics, version 20.0 (IBM Corp., Armonk, NY). A significance level of $P < .05$ was established.

Results

Participant characteristics

Of the 54 emergency health care professionals who participated in this study, 75.9% were nurses and 24.1% were physicians. The participating nurses had a mean of 20 years of health care experience (standard deviation [SD] 9.7) and a mean of 10.3 (SD 7.4) years of experience within their specialty. Emergency physicians had 3.3 (SD 1.8) years of specialty experience. All nurses were registered nurses licensed in emergency care. More than half were also licensed in critical care and prehospital care. Of the 13 emergency physicians, 11 were residents (Table 3).

Effect of the educational intervention

During the pretest (photoset A), 87.7% (474/540) of photos were correctly identified as either a PU or not a PU, and participants classified 68.5% (370/540) of photos into the correct PU category. Posttest identification and classification skills improved significantly. PU identification in photoset A improved to 95.6% (516/540; $P = .000$), and accurate classification increased to 84.1% (454/540; $P = .000$). Correct posttest identification of PUs in the combined photoset (A + B) was 95.6% (1032/1080); accurate PU classification was 79.8% (862/1080). This finding indicated significant improvement over pretest scores (photoset A) ($P = .000$). Likewise, both identification and classification of blanchable erythema improved significantly after the intervention in both photoset A ($P = .000$, $P = .000$, respectively) and photoset A + B ($P = .005$, $P = .013$, respectively) (Table 4).

Table 4. Comparison of correct identification before and after intervention.

	Pretest Photoset A (%)	Posttest Photoset A (%)	P-Value	T	Posttest Photoset A+B (%)	P-Value	T
All skin types	474/540 (87.8)	516/540(95.6)	0.000*	-6.048	1032/1080 (95.6)	0.000*	-6.358
Normal skin	52/54 (96.3)	53/54 (98.2)	0.322	-1.000	160/162 (98.8)	0.289	-1.070
Blanchable erythema	86/108 (79.6)	104/108(96.3)	0.000*	-4.203	146/162 (90.1)	0.013*	-2.564
Category 1	72/108 (66.7)	89/108 (82.4)	0.003*	-3.093	200/270 (74.1)	0.125	-1.559
Category 2	158/162(97.5)	162/162 (100)	0.044*	-2.059	269/270 (99.6)	0.104	-1.654
Category 3	52/54 (96.3)	54/54 (100)	0.159	-1.429	108/108(100)	0.159	-1.428
Category 4	54/54(100)	54/54 (100)	-	-	134/108 (96.3)	-	-

P-value for differences between pre-test and post-test calculated with paired sampled T test
*P < 0.05

Table 5. Comparison of correct classification before and after intervention.

	Pre-test Photoset A (%)	Post-test Photoset A (%)	P-Value	T	Post-test Photoset A+B (%)	P-Value	T
All skin types	370/540(68.5)	454/540 (84.1)	0.000*	-5.894	862/1080 (79.8)	0.000*	-4.661
Normal skin	45/54 (83.3)	50/54 (92.6)	0.096	-1.695	130/162 (80.3)	0.583	-0.552
Blanchable erythema	84/108 (77.8)	104/108 (96.3)	0.000*	-4.595	146/162 (90.1)	0.005*	-2.934
Category 1	56/108 (51.9)	87/108(80.6)	0.000*	-5.330	198/270 (73.3)	0.000*	-4.329
Category 2	101/162 (62.3)	118/162 (72.8)	0.034*	-2.181	203/270 (75.2)	0.003*	-3.141
Category 3	39/54 (72.2)	42/54 (77.8)	0.496	-0.685	85/108 (78.7)	0.397	-0.853
Category 4	45/54 (83.3)	53/54 (98.2)	0.010*	-2.669	102/108 (94.4)	0.051	-2.000

P-value for differences between pre-test and post-test calculated with paired sampled T test,
*P < 0.05

Table 6. Inter-rater reliability

Multi-rater kappa	Pre-test photoset A	Post-test Photoset A	Post-test Photoset AB
Identification	0.63	0.83	0.82
Classification	0.43	0.67	0.58

Figure 2. Classification of photographs in the pre-test (photoset A)

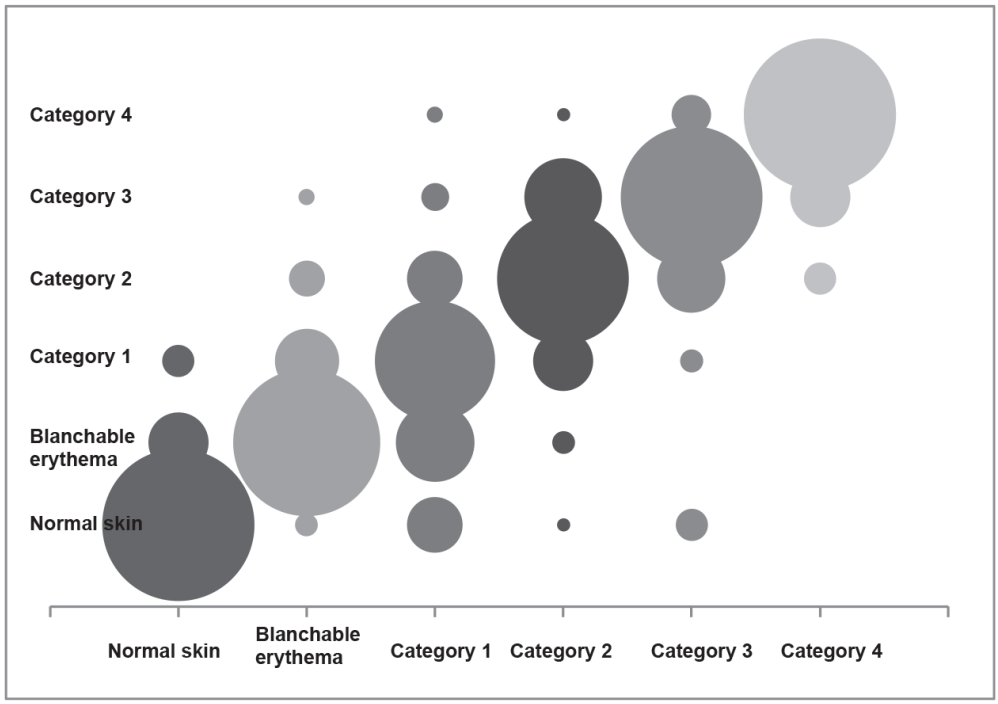
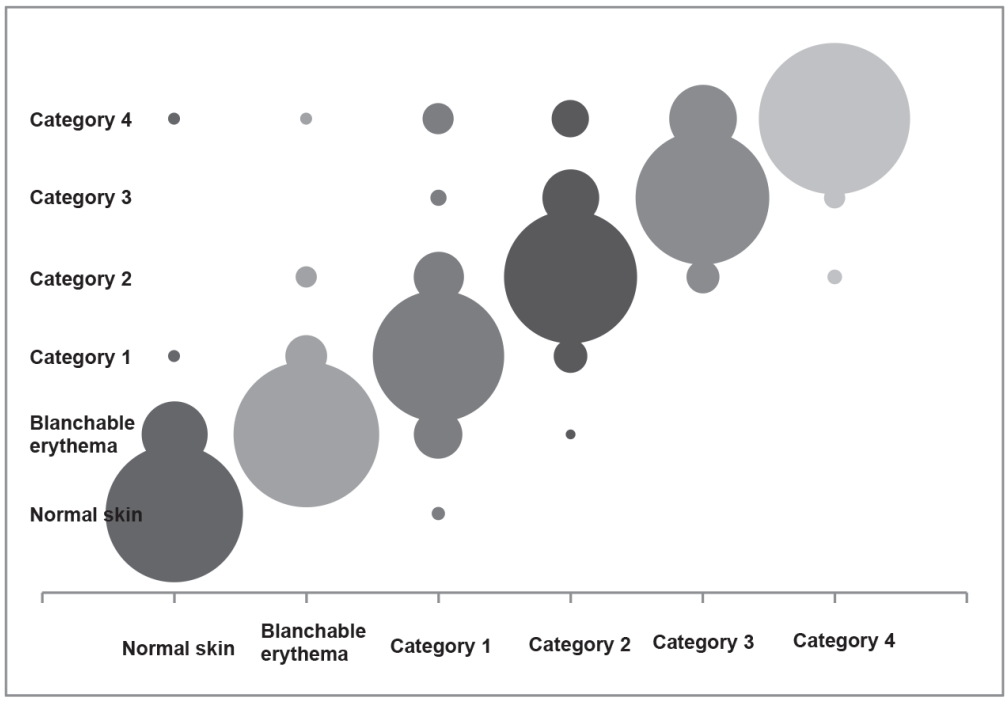


Figure 3. Classification of photographs in the post-test (photoset A+B)



Accurate classification of category 1 and 2 PUs improved significantly in both photoset A (P =.000, P = .034, respectively) and photoset A + B (P =.000, P = .003, respectively). Correct identifications are presented in Table 4, and correct classifications are presented in Table 5.

Interrater reliability

The multirater κ for PU identification increased from0.63 on the pretest (photoset A) to 0.83 on the posttest(photoset A), and it was 0.82 for photoset A + B. The multirater κ for PU classification rose from 0.43 in the pretest (photoset A) to 0.67 in the posttest (photoset A), and it was 0.58 for photoset A + B. (Table 6)

PU classification skills after intervention

On the posttest, blanchable erythema and category 4 PUs had the highest percentage of correct classification scores (90.1% and 94.4%, respectively). The most frequently misclassified photographs were those that displayed category 1, 2, and 3 PUs. Photos depicting category 1 PUs were either underclassified as normal skin or blanchable erythema (10.7%) or overclassified as category 2, 3, or 4 (15.9%). Photographs depicting category 2 PUs were either under classified as category 1 or blanchable erythema (5.2%) or over classified as category 3 or 4 (19.6%). Photographs depicting category 3 PUs were either underclassified as category 2 (4.6%) or overclassified as category 4 (19.4%). (Figures 2 and 3)

Discussion

This study investigated the effect of an educational intervention on the interrater reliability, PU identification skills, and PU classification skills of emergency nurses and physicians when tested immediately after the intervention. Study results show that interrater reliability, PU identification, and PU classification of photographs all improved, but identifying the presence of a PU in a photograph was less challenging than categorizing the same wound.

Limitations

This study has some important limitations, including the fact that the posttest was not repeated at a later date to measure information retention. Repetition of the posttest could have given more insight into the long-term effect on classification and identification skills (17). A second limitation is the sampling method. A heterogeneous group of emergency nurses and physicians was recruited for the study, using convenience sampling. Although this method could lead to selection bias, the participants were representative of personnel working at the study site. A third potential limitation is information bias.

Overall, interrater reliability, identification skills, and classification ability were higher after the intervention when photoset A was used than they were when photoset A + B was shown. This result could be explained by the fact that participants recognized wounds from photoset A that were used in the pretest. Although participants were asked not to discuss the content of the workshop, this request does not guarantee that between-subject contamination did not occur. Additionally, workshop conditions varied because of the fluctuating number of participants and the use of different conference rooms. Light intensity was inconsistent between conference rooms, which altered photo presentation quality. Together, these factors may have influenced the quality of the educational intervention and therefore the study results. A limitation to generalizability is the absence of photos depicting patients with darkly pigmented skin. PU classification in patients with dark skin is more difficult, because nonblanchable erythema and category 1 PU can easily be missed (18). Finally, the study could have been strengthened by using real patients instead of photographs. Photographic assessment of PUs can never replace examination in clinical practice, although the ethical and logistical considerations for such a study would be extensive. Moreover, in practice, trauma patients frequently come with other injuries, dirt, or blood that can hinder skin assessment.

PU classification skill improvement after an educational intervention has been previously described in 2 studies (11,19) that examined the effect of an e-learning program on PU classification skills. Results from these studies are difficult to compare with the present study, because participants types differed, sample sizes varied, and incontinence lesions were included in the photo set. Despite differences compared with the present study, authors of both previous studies reported PU classification skill improvement after an educational intervention. PU identification is the first step in the classification process. In this study, correct identification of PUs reached an almost perfect posttest score. PU classification improved to a lesser degree, but score enhancement remained significant. Interrater identification reliability rose to an "almost perfect" agreement between raters after the intervention, yet interrater classification reliability only demonstrated moderate gains. These results indicate PU identification is easier than classification. When photographs were incorrectly categorized on the posttest, they were usually classified as more severe than their actual PU category. In practice, overclassification may promote timely PU recognition but could also foster the application of premature or disproportionate interventions. Although accurate PU classification was more challenging than identification, a significant improvement occurred in correct classification of photos that displayed blanchable erythema and category 1 and 2 PUs. Nonblanchable erythema suggests increased PU risk and should therefore be interpreted as an important warning sign (20,21). Differentiating nonblanchable from blanchable erythema is essential for

early stage PU recognition. Accurate classification of blanchable erythema and category 1 PUs may be of particular importance in the emergency department. In a recent study by Dugaret et al., (14) it was reported that 4.9% of adult patients admitted to the emergency department experienced PUs, 89.5% of which were category 1 PUs. In addition to the correct classification of blanchable erythema and category 1 PU, precise identification of category 2, 3, and 4 PUs is important because these PUs are typically preexisting conditions. To optimize the identification and classification skills, additional training and education is required and needs to be extended beyond classification from photographs. Training and education in PU classification should move toward clinical examination in practice, at the bedside of the trauma patient.

Implications for Emergency Nurses

Regular skin assessment is recommended to detect PUs in an early stage (1). Denby and Rowlands reported an increased risk for PU development in patients who were admitted to the hospital through the ED (22). Therefore skin assessment, as well as PU risk assessment, should ideally start in the ED. After assessment and stabilization of emergent conditions, attention can shift toward PU prevention, identification, and classification. Every emergency nurse and physician needs to be aware of PU risk factors and should be able to recognize and classify PUs. The risk of PU development increases when trauma patients are immobilized for preventive or therapeutic reasons (23-26). Interventions need to focus on pressure relief. The period of backboard and cervical collar immobilization should be limited, because these devices exert particularly high pressure on soft tissues. Backboards—a prehospital extrication device—should be removed as soon as possible after arrival at the emergency department (27-29). Cervical collar and lateral head block times should be minimized by expediting the process of cervical spine clearance. If a patient must remain in a cervical collar for an extended period, one should remove the collar on a regular basis (while maintaining inline stabilization) to relieve pressure and inspect the underlying skin (25,26,30-33).

Conclusions

In conclusion, this study demonstrates that an educational intervention effectively improved the interrater reliability, PU identification, and PU classification skills of emergency care personnel when they were tested immediately after the intervention. After the intervention, both emergency nurses and physicians were better able to identify and classify PUs in photographs, but PU identification was more accurate than PU categorization. Although assessment and stabilization of severely injured trauma patients is the care priority, emergency personnel need to be cognizant that immobilization, medical devices, and other risk factors make the trauma patient vulnerable to PU development. PU awareness and early detection are essential for preventing PU development.

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Chapter 4

Pressure Ulcers, Indentation Marks and Pain from cervical Spine immobilization with extrication collars and headblocks; an observational study

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Abstract

Objectives

To describe the occurrence and severity of pressure ulcers, indentation marks and pain from the extrication collar combined with headblocks. Furthermore, the influence of time, injury severity and patient characteristics on the development of pressure ulcers, indentation marks and pain was explored.

Design

Observational

Study Setting

Level one trauma center in the Netherlands

Participants

Adult trauma patients admitted to the emergency department in an extrication collar combined with headblocks.

Methods

Between January and December 2013, 342 patients were included. Study outcomes were incidence and severity of pressure ulcers, indentation marks and pain. The following dependent variables were collected: time in the cervical collar and headblocks, Glasgow Coma Scale, Mean Arterial Pressure, hemoglobin, Injury Severity Score, gender, age, and Body Mass Index.

Results

75.4% of the patients developed a category 1 and 2.9% a category 2 pressure ulcer. Indentation marks were observed in 221 (64.6%) patients; 96 (28.1%) had severe indentation marks. Pressure ulcers and indentation marks were observed most frequently at the back, shoulders and chest. 63.2% experienced pain, of which, 38.5% experienced severe pain. Pain was mainly located at the occiput. BMI was significantly different between patients with and without indentation marks (z -1.9, p 0.05). Female patients experienced significantly more pain (NRS >3) compared to male patients (Chi 8.2, p 0.00). None of the investigated variables significantly increased the probability of developing PUs or indentation marks. Being a female significantly increased the likelihood of experiencing pain with 114% (OR 2.14, p 0.009), compared to being male.

Conclusions

The high incidence of category 1 pressure ulcers and severe indentation marks indicate an increased risk for pressure ulcer development and may well lead to more severe PU lesions. Pain due to the application of the extrication collar and headblocks may lead to undesirable movement (in order to relieve the pressure) or to bias clinical examination of the cervical spine. It is necessary to revise the current practice of cervical spine immobilization.

Introduction

Background

Injury from trauma is a major cause of mortality and morbidity. In Europe, almost 40 million trauma patients are treated in a hospital for injuries each year. Of these, 5.7 million are admitted to the hospital for severe injuries - more than 112 000 people per day (1). Before hospital admission, trauma patients are admitted to the emergency department (ED). Over 60 countries worldwide use the Advanced Trauma Life Support to assess and evaluate trauma patients in the ED. The program prescribes to immobilize patients with appropriate immobilization devices in case of suspected spine injury. An extrication backboard and an extrication collar, often combined with headblocks, are utilized for prehospital immobilization (2). The backboard should be removed as soon as possible after patient presentation in the ED (2-4). The extrication collar and headblocks immobilize the cervical spine. Immobilization with an extrication collar combined with headblocks should be continued without backboard, but by straight alignment of the spine and supine body position.

The extrication collar and headblocks are applied to protect the *possible* injured spine in the acute phase and will be applied temporary until injury is diagnosed or excluded. Although the (possible) injured spine is protected, the application of immobilizing devices may increase risk for pressure ulcer (PU) development and pain (5). In order to immobilize, the extrication collar and headblocks will produce succinct pressure on the skin and underlying tissues, and it is well known that PUs result from sustained pressure (including pressure associated with shear) (6).

In practice, emergency nurses noticed profound indentation marks from the extrication collar and headblocks after removal. These indentation marks demonstrate the extreme discomfort related to the collar and headblocks. They are caused by pressure and may therefore be an early sign of PU development. However, they have not been described systematically before.

Depending on the severity, PUs are known to cause pain and affect physical, social, psychological and financial aspects of health-related quality of life (7-9). Although

the application of the extrication collar and headblocks is temporary, if patients do have cervical injury and need further treatment with a long-term collar, they could be extra vulnerable for future PU development. Furthermore, the pressure from the extrication collar and headblocks, combined with the supine body position, may cause pain. It is well possible that pain and discomfort from immobilizing devices may lead to undesirable movement of the head and spine, in order to relieve the pain.

There are no studies on pain and PU development from extrication collars combined with headblocks in trauma patients (5). The purpose of this study was to prospectively describe the occurrence and severity of PUs, indentation marks and pain from the extrication collar combined with headblocks. Furthermore we explored the influence of time, injury severity and patient characteristics on the presence of PUs, indentation marks and pain in trauma patients with suspected spine injury, admitted to the ED for evaluation and treatment.

Methods

Design, setting

From January to December 2013, we conducted an observational study in a level one trauma center in the Netherlands.

Participants

All consecutive trauma patients aged ≥ 18 years admitted to the ED with standard spinal immobilization were eligible for the study. The backboard was removed before the initial assessment in the trauma room, leaving the patient in extrication collar and headblocks in supine position. Patients with existing skin breakdown, severe burn wounds (> 10% body region), and patients who were transferred from the ED to another hospital or from another hospital to our ED were excluded.

Dependent variables

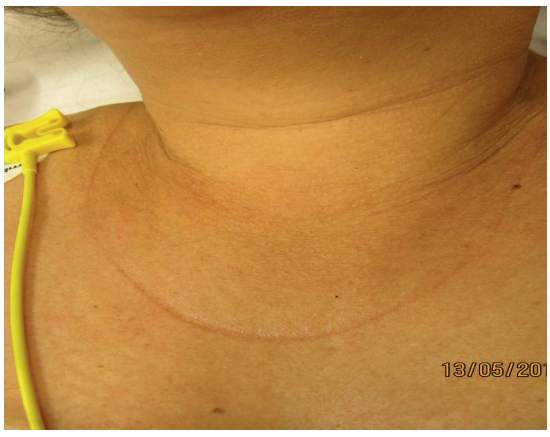
Main study outcomes were the incidence and severity of PUs, indentation marks and pain.

PUs were categorized according to the four categories of the International Pressure Ulcer Classification System (10). (Table 1) If redness was identified, a transparent disc was pressed onto the redness. If the skin under the transparent disk did not blanch, it was considered to be a category 1 PU (11). Indentation marks were defined as: ‘mild’ or ‘severe’. ‘Mild’ indentation represents indentation marks without a bordering skin reaction (example 1) and ‘severe’ indentation (example 2) represents indentation marks with bordering skin reaction (tumor and/or rubor). Pain was measured with the Numeric Rating Scale (NRS) (0-10). Pain was considered mild when a patient scored 1-3 points, moderate in 4-6 points and severe in 7-10 points.

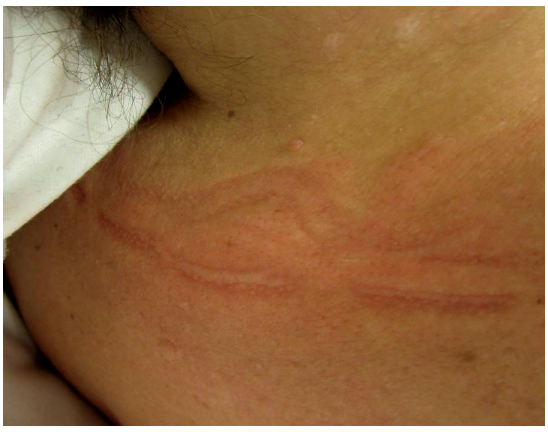
Table 1. Pressure ulcer classification

International NPUAP- EPUAP Pressure Ulcer Classification System, 2009
Category/Stage I: Non-blanchable redness of intact skin
Intact skin with non-blanchable redness of a localized area usually over a bony prominence. Discoloration of the skin, warmth, edema, hardness or pain may also be present. Darkly pigmented skin may not have visible blanching. Further description: The area may be painful, firm, soft, warmer or cooler as compared to adjacent tissue. Category/Stage I may be difficult to detect in individuals with dark skin tones. May indicate "at risk" persons.
Category/Stage II: Partial thickness skin loss or blister
Partial thickness loss of dermis presenting as a shallow open ulcer with a red pink wound bed, without slough. May also present as an intact or open/ruptured serum- filled or sero-sanginous filled blister. Further description: Presents as a shiny or dry shallow ulcer without slough or bruising. This category/stage should not be used to describe skin tears, tape burns, incontinence associated dermatitis, maceration or excoriation.
Category/Stage III: Full thickness skin loss (fat visible)
Full thickness tissue loss. Subcutaneous fat may be visible but bone, tendon or muscle are not exposed. Some slough may be present. May include undermining and tunneling. Further description: The depth of a Category/Stage III pressure ulcer varies by anatomical location. The bridge of the nose, ear, occiput and malleolus do not have (adipose) subcutaneous tissue and Category/Stage III ulcers can be shallow. In contrast, areas of significant adiposity can develop extremely deep Category/Stage III pressure ulcers. Bone/tendon is not visible or directly palpable.
Category/Stage IV: Full thickness tissue loss (muscle/bone visible)
Full thickness tissue loss with exposed bone, tendon or muscle. Slough or eschar may be present. Often include undermining and tunneling. Further description: The depth of a Category/Stage IV pressure ulcer varies by anatomical location. The bridge of the nose, ear, occiput and malleolus do not have (adipose) subcutaneous tissue and these ulcers can be shallow. Category/Stage IV ulcers can extend into muscle and/or supporting structures (e.g., fascia, tendon or joint capsule) making osteomyelitis or osteitis likely to occur. Exposed bone/ muscle is visible or directly palpable.

Example 1.



Example 2.



Independent variables

To explore the influence on the development of PUs, indentation marks and pain, the following variables were collected: time in the cervical collar and headblocks, Glasgow Coma Scale (GCS), Mean Arterial Pressure (MAP), hemoglobin level (HB), Injury Severity Scores (ISS), gender, age, and Body Mass Index (BMI). 'Time in the cervical collar and headblocks' was measured from ED admission to removal, in minutes. These variables are based on risk factors as described in the international PU guidelines from 2009 (10).

Data collection

Patients were selected for the study by senior nursing staff after primary assessment in the trauma room. Trained emergency nurses collected data just before and just after removal or replacement of the extrication collar and headblocks. Data were recorded on a structured data collection form. Nurses assessed skin areas exposed to pressure from the extrication collar and headblocks as described in literature: chin, occiput, clavicles, back, chest and ears (5). Pain scores were measured just before removal or replacement of the extrication collar and headblocks. Patients were asked to rate pain specifically related to skin areas exposed to pressure of the extrication collar and headblocks. Pain was not measured in patients with limited cognition (GCS score <14, or intoxication) or patients who were incapable to rate pain numerically. After removal of the extrication collar and headblocks, time of removal was documented, and skin areas exposed to pressure from the extrication collar and headblocks were assessed for PUs. If skin assessment was not possible in specific areas it was documented. If redness, PUs or indentation marks were present, the skin was photographed. All photographs were examined for presence and severity of indentation marks by the first author (WH). Data on potential risk factors and baseline characteristics (mechanism of injury, age, gender, and ISS) were collected from medical records (WH).

Bias

To minimize information bias, emergency nurses were trained to identify and categorize PUs from photographs prior to this study (12). During the study, the trained emergency nurses used a handout with descriptions and illustrations of PU wounds corresponding to the PU categories during data collection. Emergency nurses were trained to use the transparent disc method. During the study, inter-rater reliability was assessed. The principal investigator (WH) and seven different emergency nurses independently observed pressure areas. Observations from WH were considered as a reference. Kappa for these observations was high: 0.85 ($p<0.001$), however, due to the acute nature and often out-of-hours care for trauma patients, only 7 nurses were evaluated.

Sample size

No sample size was calculated prior to the study; whereas this was the first study on pressure ulcers, indentation marks, and pain from extrication collars and headblocks. Historical trauma data showed that 1200 trauma patients were treated each year in the study setting. Unfortunately the proportion of patients with suspected spinal injury was unclear. Therefore we chose the pragmatic approach and planned a period of recruitments of 12 months.

Missing data

In 51 patients, 59 (1.7%; 59/3361) values were missing at random on BMI (n=21), MAP (n=13), HB (n=18), ISS (n=5), "time in collar' (n=1) and GCS (n=1). We performed multiple imputations with the fully conditional specification method (13) (five iterations) on all variables.

Data analysis

The Statistical Package for the Social Sciences (SPSS) 20.0 program for data analysis was used (Version 20.0, Armonk, NY: IBM Corp.) As data were not normally distributed, continuous variables were described with medians and Inter Quartile Ranges (IQR); categorical or dichotomous variables were described with frequencies and percentages. Incidence figures were described as proportions and defined as percentage of patients with PU, indentation marks or pain; if patients had multiple PUs or indentation marks, we described the most severe lesion or mark. We constructed 95% confidence intervals (CIs) around proportions (Clopper-Pearson exact method) (14).

The two-sided Mann-Whitney test and chi-square test were used to compare risk factors in patients with and without PUs, indentation marks and pain. The SPSS program calculates the tests for all iterations, however calculates solely mean ranks for the pooled data. The Mann Whitney U-test, z values and p values were therefore calculated by hand, using the exact same formulas that were applied by the SPSS program on the five iterations. Logistic regression (enter method) was used to explore the association of time, injury severity and patients' characteristics with the development of PUs, indentation marks and pain. We used the "enter-method": all variables were entered simultaneous. We chose this analysis because this is an explorative study with a small set of independent variables. Pain was considered present at a pain score of NRS >3; only these scores were used for analysis. The level of significance was established at $p < 0.05$ for all tests.

Ethical considerations

The Medical Ethics Review Committee of UMC Utrecht stated that the Dutch Medical Research Involving Human Subjects Acts (WMO) does not apply to this study and official

IRB approval is not required under the WMO (protocol number 12/161). Informed consent for the use of data was required. After primary survey at the ED, eligible trauma patients or their legal representatives were given written and verbal information. Informed consent was asked at the ED or within 48 hours after admission (delayed consent). Where photographs were taken patients were portrayed unrecognizably.

Results

Included patients

In 2013, 623 trauma patients were admitted to the ED with suspected spinal injury; in 57 patients the extrication collar and headblocks were removed directly after arrival in the trauma room and 566 eligible patients remained. Of these, ten patients died within 24 hours without informed consent, 51 refused study participation, six patients were excluded and 13 patients were transferred to another hospital before removal of the extrication collar and headblocks. 144 patients were missed for observation either because their extrication collar and headblocks were removed outside the ED (OR, ICU or Medium Care Unit; n=52) or because the ED was so busy that patient care had to be prioritized over data collection (n=92). Finally, 342 trauma patients were included. (Figure 1)

Baseline characteristics

144 (42.1%) were female and the median age was 45 years. Mechanisms of injury were mainly falls (n=124, 36.3%), followed by car crashes (n=100, 29.2%) and cycle crashes (n=56, 16.4%). The majority of included trauma patients had an ISS score between 0-9 (235, 68.7%) and 10-15 (45, 13.2%) indicating minor and moderate injury. 38 (11.1%) and 24 (7.0%) patients had severe (16-24) to very severe (>24) injuries, respectively. Median time in the extrication collar and headblocks was 117 minutes. (Table 2)

Pressure ulcers and indentation marks

78.4% (95%CI: 73.6-82.6%) of the patients had PUs after removal or replacement of the extrication collar and headblocks in ED. 258 (75.4%) trauma patients had at least one category 1 lesion as most severe PU, and 10 (2.9%) had at least one category 2 lesion as most severe, with a mean of 2.5 lesions per patients (682/268). (Table 3) Category 1 PUs were mainly located at the chest (19.6%), back (16.1%) and the shoulders (12.6-16.9%). Category 2 PUs were located at the back and shoulders. In 221 patients (64.6%, 95%CI: 59.3-69.7%) indentation marks were identified. All indentation marks followed the pattern of the extrication collar. In 96 (28.1%) trauma patients, we observed at least one severe indentation mark, with a mean of 1.9 marks per patient (428/221). (Table 3) Mild indentation marks were mainly located at the chest

Figure 1. Inclusion schedule

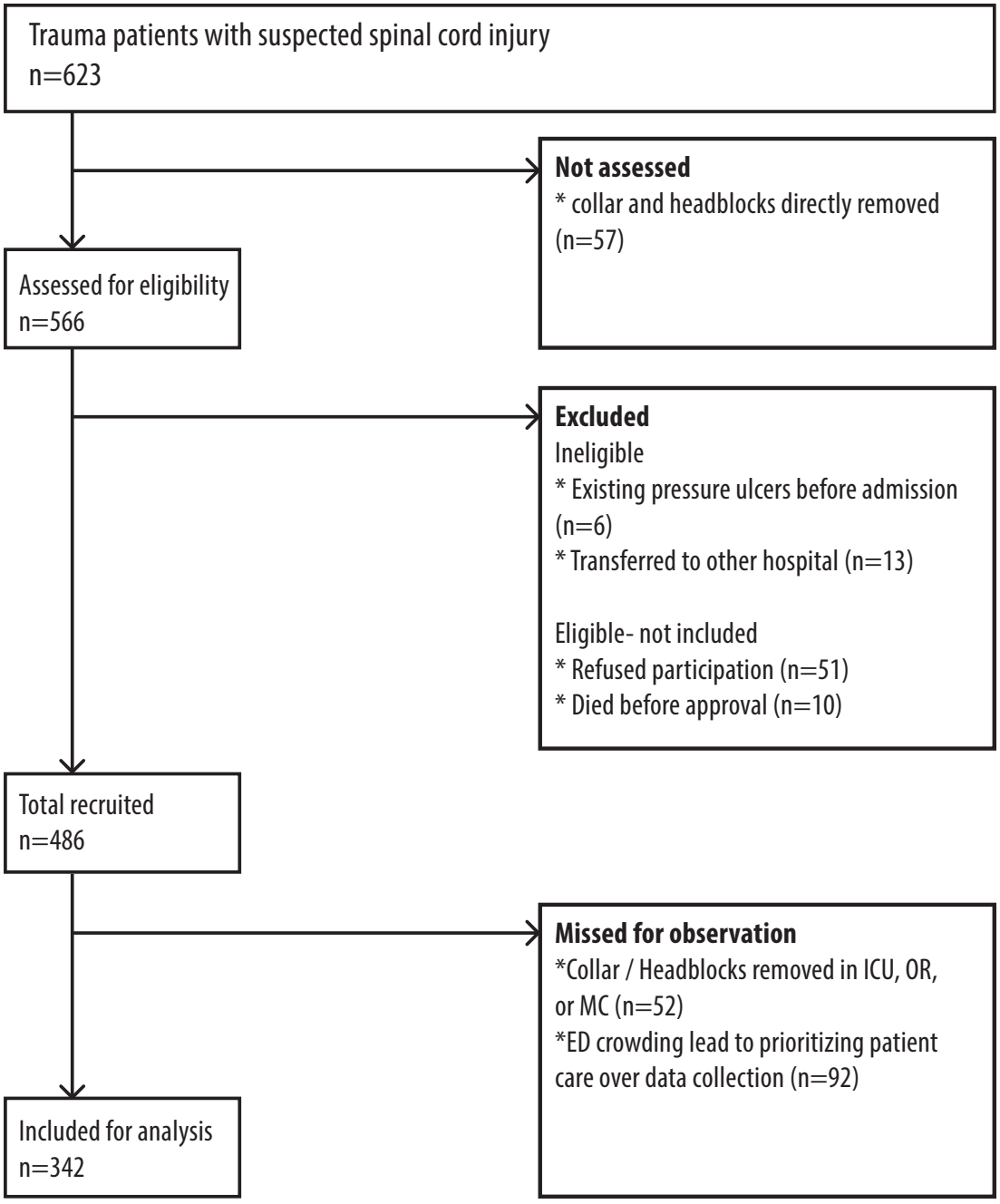


Table 2. Baseline characteristics

Patient characteristics	Value
	Median (Inter Quartile Range)
Age	45 (34)
Time in extrication collar and headblocks (minutes)	117 (61)
Female	*Frequency (Percentage)* 144 (42.1%)
Mechanism of injury	
Fall	124 (36.3%)
Car crash	100 (29.2 %)
Cycle crash	56 (16.4%)
Scooter	18 (5.3%)
Motorcycle crash	15 (4.4%)
Pedestrian struck	10 (2.9%)
Assault	8 (2.3%)
Crush	7 (2.0%)
Strangulation	1 (0.3%)
unknown	3 (0.9%)
ISS	
0-9	235 (68.7%)
10-15	45 (13.2%)
16-24	38 (11.1%)
>24	24 (7.0%)

ISS: Injury Severity Score

Table 3. Incidences

	Pressure Ulcers			**Indentation marks**		**Pain > NRS 3***			
Total n (%)	268/342(78.4)			221/342(64.6)		182/288 (63.2)			
Exact 95% confidence interval (%)	73.6-82.6			59.3-69.7		57.3-68.8			
	Blanchable redness	**Category 1**	**Category 2**	**Mild**	**Severe**	**No**	**Mild**	**Moderate**	**Severe**
n (%)	49/342 (14.3)	258/342 (75.4)	10/342 (2.9)	125/342 (36.5)	96/342 (28.1)	58/288 (20.1)	48/288 (16.7)	71/288 (24.7)	111/288 (38.5)

* NRS: Numeric Rating Scale scores; 1-3=Mild; 4-6=Moderate, 7-10=Severe.

Table 4. Group comparisons

	Indentation			**Pain**			**Pressure Ulcers**		
	No n=121	Yes n=221	Mann-Whitney U	No n=106	Yes n=182	Mann-Whitney U	No n=74	Yes n=268	Mann-Whitney U
	Mean rank score			*Mean rank score*			*Mean rank score*		
GCS	175.7	169.2	**Z[1] -0.9 p 0.4**	142.1	145.1	**Z -0.7 p 0.5**	163.4	173.7	**Z -1.2 p 0.2**
ISS	182.4	165.5	**Z -1.5 p 0.1**	150.0	141.3	**Z -0.9 p 0.4**	172.9	171.1	**Z -0.1 p 0.9**
BMI	157.6	179.1	**Z -1.9 p 0.05**	140.0	147.1	**Z -0.7 p 0.5**	166.9	172.8	**Z -0.5 p 0.7**
Age	168.3	173.6	**Z -0.4 p 0.7**	146.2	143.5	**Z-0.3 P 0.8**	155.5	175.9	**Z-1.6 p 0.1**
MAP	165.9	175.6	**Z -0.8 p 0.4**	144.3	144.6	**Z -0.03 P 0.97**	173.5	171.0	**Z-0.2 p 0.8**
HB	165.4	175.9	**Z -0.9 p 0.4**	154.6	138.6	**Z-1.6 p 0.1**	161.6	174.2	**Z-1.0 p 0.3**
Time in collar	175.9	169.1	**Z -0.6 p 0.5**	138.1	148.2	**Z-1.0 p 0.3**	183.1	168.3	**Z-1.1 p 0.3**
	n (%)		Chi-square	*n (%)*		Chi-square	*n (%)*		Chi-square
Gender									
Male	72 (59.5)	126 (57.0)	**Chi[2]0.2**	72 (67.9)	92 (50.5)	**Chi 8.2**	38 (51.4)	160 (59.7)	**Chi 1.7**
Female	49 (40.5)	95 (43)	**p 0.7**	34 (32.1)	90 (49.5)	**p 0.00**	36 (48.6)	108 (40.3)	**p 0.2**

[1] Z Statistic, [2] Pearson Chi-square

GCS: Glasgow Coma Scale; ISS: Injury Severity Score; BMI: Body Mass Index; MAP: Mean Arterial Pressure HB: Haemoglobin.

Table 5. Logistic regression (Enter method)

	Pressure Ulcers			**Indentation marks**			**Pain > NRS 3**		
	OR	**95% CI**	**P value**	**OR**	**95% CI**	**P value**	**OR**	**95% CI**	**P value**
GCS	1.06	0.93-1.22	0.39	0.94	0.81-1.09	0.38	0.96	0.67-1.39	0.83
ISS	1.00	0.99-1.04	0.91	0.99	0.96-1.01	0.27	0.99	0.96-1.03	0.70
Age	1.01	1.00-1.03	0.09	1.00	0.99-1.02	0.61	0.46	0.98-1.01	0.52
Female**	0.78	0.46-1.43	0.43	1.19	0.71-2.01	0.50	2.14	1.21-3.80	0.009*
BMI	1.00	0.95-1.06	0.92	1.05	1.00-1.10	0.06	1.05	0.99-1.11	0.11
MAP	0.99	0.97-1.01	0.26	0.99	0.98-1.01	0.59	0.99	0.98-1.02	0.94
HB	1.16	0.81-1.67	0.41	1.15	0.86-1.53	0.36	1.03	0.75-1.42	0.96
Time in collar	1.00	0.99-1.00	0.12	0.99	0.99-1.00	0.31	1.00	0.99-1.00	0.93

* $p \leq 0.05$

** Male = reference category

GCS: Glasgow Coma Scale; ISS: Injury Severity Score; BMI: Body Mass Index; MAP: Mean Arterial Pressure HB: Haemoglobin.

(15.5%), back (10.7%) and shoulders (13.5%). Severe indentation marks were mainly located at the back (14.6%). Skin inspection was not possible for occiput (96 times), back (71 times) and chin (2 times), due to wounds or the inability to move.

Pain

182 patients (63.2%, 95% CI: 57.3-68.8%) experienced pain (NRS >3). 48 (16.7%) experienced mild pain (NRS 1-3), 71 (24.6%) moderate pain (NRS 4-6) and 111 (38.5%) severe pain (NRS 7-10). Pain occurred most frequently at the occiput (160 times). (Table 3) In 288/342 (84%) patients, pain scores were rated. Eight patients were not capable to describe their pain on a numeric scale, seven patients were missed and in 39 patients it was impossible to rate their pain due to impaired cognition.

Influence of time, injury severity and patient characteristics

BMI was significantly different between patients with and without indentation marks (z -1.9, p 0.05). Female patients experienced significantly more pain (NRS >3) compared to male patients (Chi 8.2, p 0.00). (Table 4) None of the investigated variables significantly increased the probability of developing PUs or indentation marks. Being a female significantly increased the likelihood of experiencing pain with 114% (OR 2.14, p 0.009), compared to being male. (Table 5)

Discussion

This is the first study on PUs, indentation marks and pain from the extrication collar and headblocks, in real trauma patients. We found very high incidence figures of PUs (78.4%), indentation marks (64.6%), and pain (63.2%).

The incidence of category 1 PUs was very high in our sample. Although category 1 is reversible in most patients, it indicates an increased risk for PU development, and may develop into a more severe PU (6,15-17). In our study, 2.9% already had a category 2 PU.

The increased PU risk in our sample may also be demonstrated by indentation marks. This is the first study in which skin deformation from pressure (indentation marks) in humans was described. These indentation marks were most severe at the back and shoulders. Although pressure came from the extrication collar and headblocks, the indentation marks clearly followed the pattern of the extrication collar. Padding from the extrication collar was easily displaced in these locations, and the stiff material of the collar indented the skin on the back and shoulders. Results from laboratory and animal studies indicate that deformations of the tissue (in our study caused by the stiff material of the extrication collar) may play a role in cell damage (17,18). The severe indentation marks (including tumor and rubor), may be an inflammatory reaction and thus a first sign of tissue damage. Especially in case of injury and long-term collar treatment, this

may lead to more severe PUs.

Severe pain (NRS 7-10) was experienced in 38.5 % of the examined patients. Although scientific evidence is lacking, practice shows that severe pain from pressure leads to agitation and the urge to move, in order to relieve the pressure. We need to realize that high pain scores hinder the main purpose of the extrication collar and headblocks, which is immobilization. This is potentially harmful, whereas in case of cervical injury, the consequences of movement may be fatal. Furthermore, pain can bias in the clinical evaluation of the C-spine, which results in prolonged immobilization.

Pain occurred most frequently at the occiput. This can be explained by the fact that trauma patients remain in supine position, while in extrication collars and headblocks. This position increases the mechanical load on the occiput. The increased mechanical load on the occiput could lead to PU development on the occiput, however, in our study, most of the PUs were located on the back and shoulders. This is deviant from literature while severe occipital PUs from cervical collars are described as a complication of collar use (19-22). The inspection of the occipital area is a challenge, which may explain the relatively small numbers of occipital PUs in our study. The inability to turn, hair, wounds, dirt or stains hinder proper inspection. Occipital PUs may therefore be detected in a later but worsened stadium (22).

None of the investigated variables were significantly associated with the development of PUs or indentation marks. However, increased age may play a role in PU development (OR 1.01, p 0.09), and BMI in the development of indentation marks (OR 1.04, p 0.06). Age is a known risk factor for PU development, (6,17) and BMI may increase the probability to develop indentation marks as adipose tissue may be more sensitive to indentation (17). A bigger sample size would have decreased the risk for a type 2 error, and thus increased the possibility of finding significant variables associated with PU development or indentation marks.

We did find gender (female) to be significantly associated with pain from the extrication collar and headblocks. This may be explained by the fact that there might be sex-related differences in pain experience. Four studies including healthy volunteers and one study with surgical patients reported significantly higher pain ratings in females compared to males (23-27). Another explanation may be found in the fact that female and male skulls feature morphological differences (28,29). Although the extrication collar comes in different sizes, and although anatomical differences between adults and children are considered, no differences in gender are considered in the design. If the design of the cervical collar has actually been based on male features, pain could also be associated with a poor collar-fit. The application of cervical collars in trauma patients with suspected spinal injury is currently under debate, because of the possible complications. Next to PU development and pain, cervical collars may increase intracranial pressure, and complicate airway management (30-32).

Holla (33) recommends applying the headblocks without the extrication collar (while strapped to a backboard). In his study, the extrication collar did not provide significantly more immobilization compared to immobilization with headblocks alone. Generalization of these results into ED practice is difficult; the study had a small sample size, and participants were strapped to a backboard, which is used for extrication and transportation only (and directly removed in the ED) (2,2-4).

Trauma patients with suspected spinal cord injury should be protected adequately, but we need to reconsider the current practice and used materials. Therefore we strongly recommend seeking safe alternatives to immobilize trauma patient with suspected cervical spine injury. We need to cooperate with industrial designers to develop alternative collars or devices for cervical immobilization, considering different body morphologies. The alternative devices should provide sufficient immobilization, but this should go hand-in-hand with comfort and feasibility. Furthermore, we should minimize time in the extrication collar. This can be achieved by prioritizing clinical clearance and facilitation of timely radiologic imaging and assessment.

Limitations

There are some limitations that should be addressed. There may be a risk for selection bias: a large proportion of eligible trauma patients (n=144) were not included in this study. And although the baseline characteristics (age, mechanism of injury and gender) of this group were comparable to the included patients, 52 of the missed patients were critically ill. These patients were hospitalized and transferred to the ward (Intensive Care Unit, Medium Care Unit) or Operating Room, before removal of the extrication collar and headblocks, due to their needs for immediate treatment. Critically ill patients are at higher risk for PU development, while their condition may lead to poor perfusion, bad skin status and immobility, which are known risk factors for PU development (6,10,34). Therefore, our current study results may underestimate the problem compared to the true clinical picture.

This large proportion of missed patients underlines the fact that research in the population of trauma patients in the ED is challenging. Trauma care is acute, not predictable and is provided day-and-night. Therefore, we selected the most pragmatic approach of data collection; by trained emergency nurses. Although data collection by multiple individuals enhances the risk for observer bias, training minimized this bias (12).

The pain scores from the extrication collars and headblocks might be biased by other distracting injuries. To minimize this bias we asked alert and awake patients specifically for pain related to the extrication collar and headblocks. Although the influence of distracting injuries is difficult to eliminate in this patient category, we did not find a correlation between pain scores and ISS score. In practice, we observed that pain

immediately disappeared, once the extrication collar and headblocks were removed.

There was a risk for information bias, whereas the reliability of the method used for distinction between blanchable redness and non-blanchable redness (i.e. category 1 PU) is ambiguous. Currently there are two methods: the 'transparent disc method' and the 'finger-method'. The methods comprise pressing a transparent disc or finger on the reddened skin to see if it blanches. The literature is not conclusive about which method is the most reliable. Vanderwee et al. found high agreements between the two methods, but slightly more sensitivity for the 'transparent disc method' (35). Kottner et al. (36) reported a higher possibility of detecting a non-blanchable redness with the 'finger-method', compared to the 'transparent disc method', however accuracy of the methods was not studied. In order to increase reliability of the data collection we intentionally chose one of the two methods and considered the 'transparent disc method' as most reliable. All emergency nurses were trained to apply the latter method.

A last issue is the reliability of distinguishing between category 1 and blanchable redness on skin with indentation marks. The bordering skin reaction (tumor, rubor) from the indentation marks may influence pressure distribution from the disc on the skin or lead to misinterpretation of redness. Unfortunately, there are no studies on diagnostic reliability of category 1 and indented skin.

In summary, we found a high incidence of category 1 PUs and severe indentation marks and high pain scores from the application of the extrication collar and headblocks. Time, injury severity and patient characteristics were not associated with PUs, and indentation marks, however being female was significantly associated with pain from the extrication collar and headblocks. Cervical immobilization for preventive reasons can be lifesaving, but it is necessary to revise the current practice of cervical spine immobilization in the ED in terms of procedures and material use in order to decrease PU risk and pain.

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Chapter 5

For discussion

A new protocol, is the spine still safe?

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Abstract

The latest version of the Dutch National Protocol Ambulance Care (Landelijk Protocol Ambulancezorg LPA 8), introduced on 1 January 2015, contains too few guarantees of the safety of trauma patients in whom spinal immobilization has to be performed. A number of strict indications have been removed and too much freedom is also permitted with respect to implementation. Although the previous standard method using a spinal board, collar and blocks did have disadvantages, the new operating method has been insufficiently substantiated and, in addition, is not well matched to the protocols of Accident and Emergency departments. It is vital that the agencies involved collaborate to reach a joint solution.

Introduction

On January 1st 2015, the eighth version of the 'National Protocol Ambulance-care' (LPA 8) has been introduced (1). The protocol is designed as a guideline for reliable medical practice in ambulance care and contains a number of sub-protocols, including the protocol 'spinal immobilization'. This 'spinal immobilization' protocol is one of the sub-protocols in LPA 8 that has been revised relative to the former LPA protocol version 7.2. We fully support the initiative of 'Ambulancezorg Nederland' to review the current standard of spinal immobilization, as this current standard has several unintended effects for trauma patients, such as anxiety, agitation or pressure ulcer development. Yet, we have questions about the revisions. According to the authors of LPA 8, the revisions are evidence-based, but how did they collect and evaluate the evidence? Can this justify the major revisions? And are these revisions truly beneficial to the trauma patient?

With this paper, we hope to initiate a discussion in order to support the development of safe and reliable trauma care throughout the entire chain of care.

Main revisions

In the prehospital phase, ambulance nurses assess the risk for spinal injury in trauma patients. In case of suspected spinal injury, spinal immobilization is initiated, in order to minimize the risk of secondary neurological damage. LPA 7.2 included a stepwise clinical decision rule for the ambulance nurse to determine whether there was an indication for spinal immobilization. This clinical decision rule included the need for endotracheal intubation, decreased Glasgow Coma Scale score and the trauma mechanism. Furthermore, clear-defined criteria were used; spinal tenderness, neurological decline, intoxication, facial injuries, distracting pain, skull fractures, seizures and inadequate patient communication. If at least one of these criteria was met, the spinal column was to be immobilized with a backboard combined with head blocks and an extrication collar.

LPA 8 introduces important revisions of both the indication as well as the application of spinal immobilization in trauma patients. First - to our surprise - not all of the above clear-defined criteria are maintained. The new decision rule allows room for individual assessment. This is remarkable, as it is known that accurate clinical decision rules with clear-defined criteria can minimize the risk of undetected spinal injury. Second, three different methods of spinal immobilization are described; backboard, vacuum mattress and the stretcher, combined with head blocks. However, it remains unclear when the extrication collar should be applied. Third, the new spinal immobilization protocol creates the impression that immobilizing the total spine, including the cervical spine,

may be omitted more frequently. The cervical spine will not be immobilized in mobile patients, children and patients with neurologic injury. This does not seem logical, as neurologic injury increases the risk of cervical injury (2). Furthermore, the protocol states that alert patients can be transported in an upright position, immobilized in a vacuum mattress, because spinal immobilization should not lead to unnecessary delay.

Scientific evidence

LPA 8 comprises accessible and feasible protocols, and according to the introduction section, the authors followed the methodology of evidence-based guideline development (3). Furthermore, concepts were presented to scientific and professional associations. However, the revised spinal immobilization protocol lacks a clear and transparent scientific rationale. As a consequence, it is difficult to judge the validity of this protocol, both for the ambulance nurses and for their partners in the acute care chain.

First, the methodology of the literature search and selection is unclear. The quality assessment of selected literature is completely lacking. The revisions of both the indication for as well as the method of spinal immobilization in LPA 8 are based on 11 literature references, of which 5 reported a consensus statement, and 1 contains an international guideline; the addendum to the 'ATLS manual'. Two studies were performed in prehospital trauma care in pediatrics, of which only 1 describes spinal immobilization in pediatrics. All in all, only two original studies were used to substantiate the revisions. It appears that the reduced application of the extrication collar in case of suspected spinal injury has been based on these two studies. The first study is a review on disadvantages of immobilization with an extrication collar, including pressure ulcers, increased intracranial pressure and difficulties in airway management (4). The review does not systematically describe the quality assessment of the included studies. Therefore, it is difficult to correctly interpret findings and recommendations. The second study examined the added value of the extrication collar in addition to immobilizing the cervical spine with head blocks (5). This 'proof of principle' study, included 10 healthy volunteers immobilized on a backboard. Therefore, results cannot be extrapolated to trauma patients.

Although LPA 7.2 also has no scientific rationale, we sincerely question to what extent the "level of evidence" in LPA 8 is sufficient to substantiate such major revisions. The authors seem to justify these major revisions with the argument that the positive effects of preventive spinal immobilization "have never been unequivocally demonstrated in clinical studies". While this may actually be correct, spinal injury is very rare and large numbers of patients are needed to demonstrate the effect of spinal immobilization (6). The fact that it is difficult to show a positive effect does not mean that immobilization would have no positive effect or is even redundant.

In our opinion, the authors of LPA 8 did not sufficiently weight the described disadvantages of spinal immobilization against the consequences of not immobilizing the cervical spine. The latter can have fatal consequences. It is clear that more scientific evidence is needed to accurately improve the indication and methods for spinal immobilization (6,7).

Implications for practice

The major revisions in the spinal immobilization protocol already caused confusion and uncertainty in the emergency departments of receiving hospitals. Not all partners in the acute care chain and their scientific associations appear to have been sufficiently involved in the development of LPA 8. Emergency departments are not convinced by the revised protocol and the preparations for introduction of this new protocol in practice have been absolutely insufficient. The indications for spinal immobilization as applied in receiving hospitals differ from LPA 8. This has led to confusion and lack of understanding in the trauma room. Compared to LPA 8, receiving hospitals use internationally applied clear-defined and strict criteria to determine if spinal immobilization is indicated. As a result, more trauma patients are considered at risk for spinal injury. Some of the patients without spinal immobilization, still receive spinal immobilization based on the hospital criteria after arrival in the trauma room.

Furthermore, the use of new materials and different immobilization techniques, leads to practical obstacles during the transfer to the trauma room. How does one transfer the patient from a vacuum mattress to a trauma bed, and what method should be used for patients in an upright position? Coordination between the ambulance services and the receiving hospitals is essential to structure the transition from the pre-hospital phase to the hospital phase. Discussions should be avoided to guarantee safe care for our trauma patients.

Conclusion

Pre-hospital spinal immobilization remains necessary to protect the patient during the transfer from the scene of accident to the hospital. The current method of spinal immobilization with a backboard, extrication collar and headblocks has disadvantages and needs to be revised. We need to look for alternative methods and materials. LPA 8 made the first step, however we consider this step to be too large and scientifically insufficiently substantiated. Both the indication and method of spinal immobilization are now susceptible to individual perception and the revisions have not been communicated sufficiently. This leads to lack of clarity for both the users and the partners in the acute care chain, resulting in endangerment of the most vulnerable trauma patients with possibly unstable spinal injury. Let us collaborate to reach consensus and to ensure that all involved partners support the new spinal immobilization protocol.

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Chapter 6

Pressure Ulcers in Trauma Patients with Suspected Spinal Injury: a Prospective Cohort Study with emphasis on device-related Pressure Ulcers

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Abstract

Of all patients in a hospital environment, trauma patients may be particularly at risk for developing (device-related) pressure ulcers (PUs), because of their traumatic injuries, immobility, and exposure to immobilizing and medical devices. Studies on device-related PUs are scarce. With this study, the incidence and characteristics of PUs and the proportion of PUs that are related to devices in adult trauma patients with suspected spinal injury were described. From January–December 2013, 254 trauma patients were visited every 2 days for skin assessment. The overall incidence of PUs was 28.3% (n = 72/254 patients). The incidence of device-related PUs was 20.1% (n = 51), and 13% (n = 33) developed solely device-related PUs. We observed 145 PUs in total of which 60.7% were related to devices (88/145). Device-related PUs were detected 16 different locations on the front and back of the body. These results show that the incidence of PUs and the proportion of device-related PUs is very high in trauma patients.

Introduction

Although knowledge and awareness of pressure ulcer (PU) development has improved over the last few decades, PUs are still a threat to hospitalized patients. In 2013, the prevalence of PUs in all types of health care institutions in the Netherlands was the highest in general hospitals (8.7%), (1) indicating that hospitals are a high-risk environment. PUs cause pain and affect physical, social, psychological and financial aspects of health-related quality of life (1-3). In the new international guidelines, a PU is defined as 'localized injury to the skin and/or underlying tissue, usually over a bony prominence, resulting from sustained pressure (including pressure associated with shear). A number of contributing or confounding factors are also associated with PUs, of which impaired mobility is a major factor' (4,5). This definition emphasizes the major role of immobility in PU development. Immobility exposes people to pressure and shear forces on one body location for prolonged periods of time. Therefore, of all patients in a hospital environment, trauma patients with suspected spinal injuries may have a particular risk for developing PUs. They are intentionally immobile from the scene of accident onward to prevent inadvertent injury to the spinal cord. Immobilization is achieved with a backboard, extrication collar and headblocks (6). Immobilization ends after spinal injury is ruled out but continues in case of a diagnosed injury. Besides spinal injury, further injuries can lead to extended periods of immobilization. Next to immobility, trauma patients are likely to be exposed to other risk factors for PU development. Their injuries may lead to decreased sensation; direct tissue damage; decreased dermal perfusion because of hypovolemic shock; altered nutrition; and surgical interventions. All of these conditions are known to increase PU risk (4,5,7). The fact that trauma patients are frequently exposed to immobilizing and medical devices may also play a role in their increased PU risk. Immobilizing devices are used as prevention(extrication collar) or treatment (casts, external fixation), and medical devices are used to monitor or manage the patient's condition(endotracheal tubes, oxygen masks, nasogastric tubes, urinary tubes or restraints). It is known that adult patients with medical devices should be considered at risk for PU development (4,8). PU incidence in trauma patients has been reported as 30.6%,but the studied sample was small (n=36), and the results are dated (9). In a systematic review, the application of immobilizing devices (cervical collars, backboards, vacuum mattresses)has shown to increase PU risk in several studies, but most studies included healthy volunteers (10). There are only two prospective studies that focused solely on PU incidence from cervical collars in trauma patients. Powers et al. reported an incidence of 6.8% in 484 trauma patients from semi-rigid collars, (11) and Molano et al. found an incidence of 23.9% in 94 trauma patients from extrication collars (12). Furthermore, severe injuries, length of admission and limitation in mobility are described as possible risk factors for PU development in trauma patients (11,12).

In summary, trauma patients may be a vulnerable patient group for PU development. Furthermore, it is unclear which proportion of the PUs in trauma patients is related to devices. In this study, we describe the incidence and characteristics of PUs, and the proportion of PUs that are related to devices, in adult trauma patients with suspected spinal injuries admitted to the hospital for the treatment of acute traumatic injuries.

Methods

Design and setting

Between January and December 2013, a prospective observational cohort study was conducted in a trauma center in the Netherlands. This is a level one trauma center, providing the highest level of trauma care.

Participants

All consecutive trauma patients transported to the emergency department on a backboard, with extrication collar and headblocks, were eligible for participation. Inclusion criteria were (i) trauma patients aged ≥ 18 years; (ii) standard pre-hospital spinal immobilization (i.e. backboard, headblocks and extrication collar); and (iii) admitted to the hospital through the emergency department for treatment of acute traumatic injuries. Exclusion criteria were (i) existing skin breakdown before admission; (ii) severe burn wounds (10% body region); and (iii) transferred from the emergency department to another hospital.

Standard procedures for a suspected spinal cord injury

The backboard should be used as an extrication and transportation device only and was therefore directly removed after arrival in the crash room in the emergency department, before the initial assessment (13). Trauma patients remained immobilized, with an extrication collar and headblocks, in the supine position until injury of the cervical spine was excluded or diagnosed. Cervical spine injuries were excluded by radiology [computed tomography (CT) scans] in combination with clinical examinations. If radiology excluded the injury, but a clinical examination was impossible (in case of intoxicated, unconscious or sedated patients), cervical spine injury could not be excluded. In these patients, the clinical examination was postponed, and the extrication collar and headblocks were replaced by a semi-rigid collar (Philadelphia®, Philadelphia Cervical Collar Co, Thorofare,NJ). If patients were deeply sedated and admitted to the intensive care unit (ICU), the cervical spine was immobilized with straps on the forehead and lateral support, which was replaced with a Philadelphia® collar once patients regained consciousness. In case of diagnosed cervical injury, patients were further immobilized with a halo brace or Philadelphia® collar or underwent surgery, as indicated.

Preventive interventions during admission

All hospitalized patients were on a standard pressure distributing mattress. If nurses identified PU risk or discovered PUs, patients were placed on the appropriate dynamic air mattresses (Promatt®, Joerns, Houten, The Netherlands or Plexus AutoSure Float®, Scan Mobility LTD, Lancashire, UK). During an ICU stay, all patients were on a Totall Care SpO2RT® ICU bed (Hill-Rom, Chicaco, IL, USA) along with pressure distributing functions, these mattresses were equipped with mechanisms to achieve various body positions. If patients were bed-bound, they were repositioned in bed for at least every 2–4 hours. Repositioning in bed was not possible in case of hemodynamic instability, instable fractures or increased pain because of the movement of limbs. Institutional guidelines prescribed the screening of all patients for malnutrition (Malnutrition Universal Screening Tool) (14). In case of risk of malnutrition, appropriate dietary interventions were taken.

Consent and data collection

After a primary survey in the emergency department, eligible trauma patients or their legal representatives were informed with written and verbal information. Informed consent was requested within 48 hours after admission (delayed consent). After inclusion, patients were followed up until discharge from the hospital or death. The 'transparent disc method' was used to distinguish between blanchable and non-blanchable redness (i.e., category 1 PUs). This method consists of pressing a transparent disc on the red skin. If the skin under the transparent disk does not blanch, it is considered to be a category 1 PU (15). If a PU was detected, the course of development was monitored. A nurse scientist, specialized and trained in PU care, collected data on a structured data collection form. Data collection started within 24 hours after emergency department admission. If patients were admitted on Wednesday or Saturday, data collection started within 48 hours. Thereafter, patients were visited every 2 days. All patient visits were planned during daily care routines. In case of uncertainty concerning categorization of the PUs, the nurse scientist consulted an expert. To reach consensus in categorising the injury, photographs and clinical descriptions were used and discussed during the consult. If patients were lost to follow-up after inclusion, they were excluded from analysis. The Medical Ethics Review Committee of participating institute stated that the Dutch Medical Research Involving Human Subjects Acts (Wet Medisch-Wetenschappelijk Onderzoek) does not apply to this study and official approval by the Institutional Review Board is not required (protocol number 12/161).

Outcomes

The main study outcomes were the incidence and characteristics of PUs. In order to differentiate between PUs related to devices and PUs not related to devices, PUs

that were not related to devices were defined as ‘pressure ulcers’ and PUs that were related to devices were defined as ‘device-related pressure ulcers’. PUs were defined as ‘device-related’ if the nurse scientist identified a visible relation to devices. PU incidence comprised the number of patients that developed PU(s) during the study period. Characteristics comprised the severity, location (anatomical site), time to development and (where applicable) relation to (medical or immobilizing) device. If patients developed PUs, follow-up was continued, and the highest PU category was used to describe the severity (according to the International Pressure Ulcer Classification System) (7). Types of immobilizing devices included cervical collars, casts, splints, external fixation or HALO frames. Types of medical devices were endotracheal tubes, oxygen masks, nasogastric tubes, urinary tubes, thromboembolic stockings, linen savers (cotton-woven blankets used as repositioning aids or mattress protectors) or restraints.

Baseline characteristics

Baseline characteristics were collected from medical records (mechanism of injury, gender, age, body mass index, injury severity score, length of stay in the emergency department and hospital and type of ward) and observations (skin pigmentation). Injury Severity Score (ISS) between 0 and 9 were considered mild injuries, between 10 and 15 were moderate, 16–24 severe and >24 very severe injuries (16). Skin pigmentation was determined using the Fitzpatrick scale for skin type (17). At admission, PU risk was calculated with the Braden Scale. The total Braden Scale scores were used as an indicator for PU risk (range 6–23), and scores >18 indicated no risk (18).

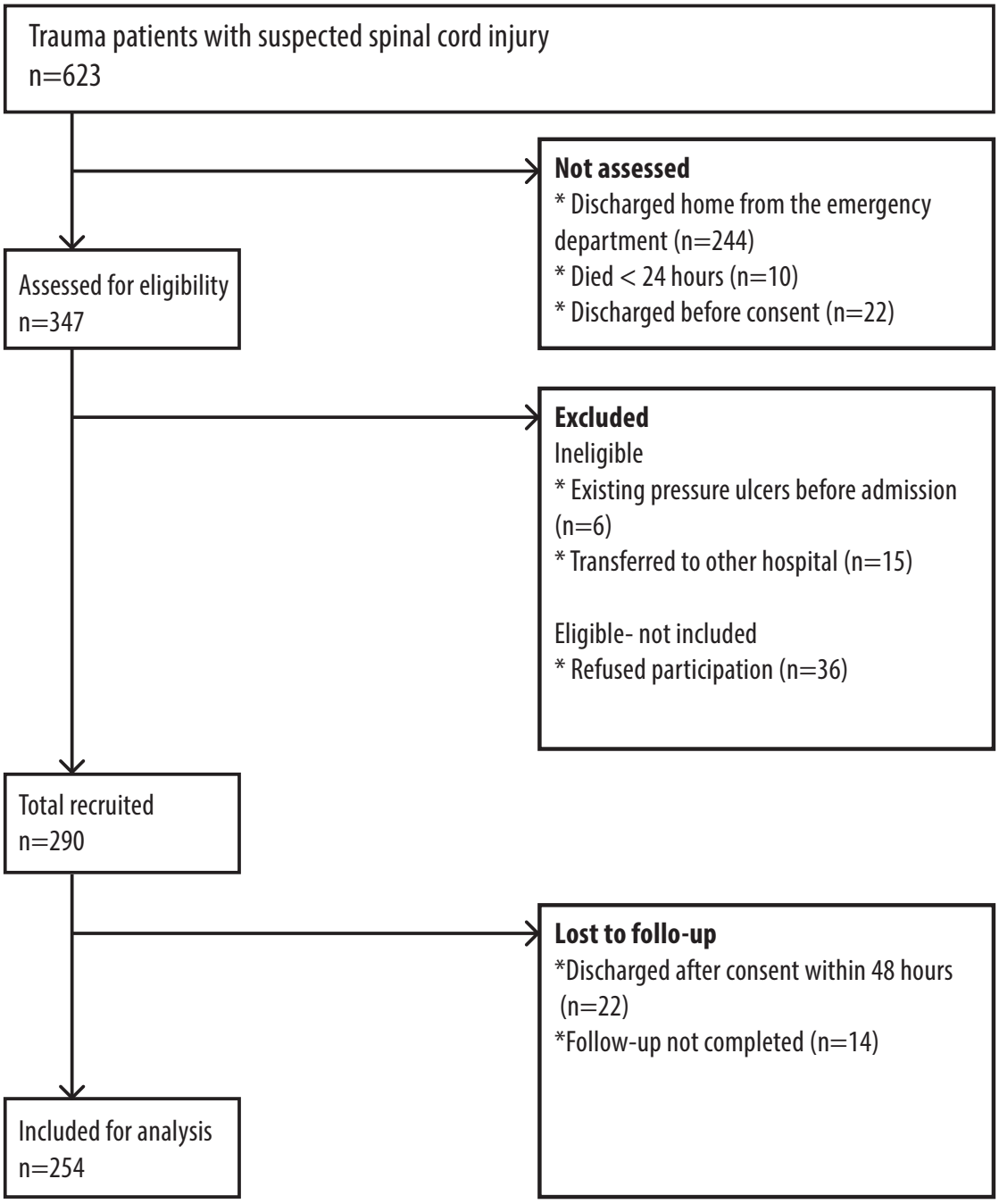
Sample size

Because this is the first prospective study on PU development in trauma patients with suspected spinal cord injury, we were unable to calculate the sample size. Estimation of the sample size was challenging. Historical trauma data revealed that 1200 trauma patients are treated each year in the study setting, but the proportion of patients with suspected spinal injuries in this group was unclear. Therefore, we chose a pragmatic approach and planned a period of recruitment of 12 months.

Statistical methods

PU incidence was defined as a proportion: the number of patients who developed at least one (device-related) category1–4 PU within the total sample. We constructed 95% confidence intervals (CIs) around proportions (Clopper-Pearson exact method). The PU severity, location and relationship with devices were described and presented as frequencies and percentages. Time to PU development was defined as the number of days between emergency department admission and the first observation of a PU. Missing data (1.5%) were not replaced or imputed. Baseline characteristics were

Figure 1. Flowchart inclusion



described as means, standard deviations (SDs) and ranges for continuous variables and frequencies and percentages for categorical or dichotomous variables. When data were not normally distributed, the median and the interquartile range (first Q1, third quartile Q3) were described. We used SPSS 20.0 to describe our outcomes and variables (Version 20.0, IBM Corp., Armonk, NY).

Results

During the study in 2013, 623 trauma patients were admitted to the emergency department with suspected spinal injuries. Of these, 244 were discharged from the emergency department,10 died in the emergency department and 22 patients were discharged before consent. The eligibility of 347 was assessed. Based on the exclusion criteria, 21 were excluded, and 36 refused participation. Finally, 290 patients were recruited for the study, and 36 patients were lost to follow-up. Ultimately, 254 trauma patients were included for analysis. (Figure 1)

Baseline characteristics

The median (Q, Q3) age was 52 (32, 65) years. and 161 (63.4%)were male. Mechanisms of injury were mainly falls (n=106,41.7%), followed by cycle crashes (n=52, 20.5%) and car crashes (n=40, 15.7%). In our sample, 140 patients suffered from mild to moderate injuries (35% ISS 0–9 and 20.1% ISS 10–15). 114 patients were severely to very severely injured (25.2% ISS 16–24 and 19.7% ISS >24). Median time (Q1, Q3) in the emergency department was 213 (152, 278) minutes, and patients were hospitalized for a median (Q1, Q3) of 5.0 (5, 21) days. Forty-four patients were admitted to the ICU for a median (Q1,Q3) of 4.5 (2, 9) days and 98 to the medium care unit for a median (Q1, Q3) of 2.0 (1, 4) days. The majority of the patients had a pale to light brown skin pigmentation (n=233, 91.6%). The mean (SD) Braden Scale score during admission was 15.9 (4.6). (Table 1)

Pressure ulcers Incidence and characteristics

The overall incidence of PUs was 28.3% (n=72, 95% CI 22.8–34.3%). The majority of the PUs were observed within the first week of admission (n=63, 87.5%). The incidence of patients with solely device-related PUs was 13% (n=33, 95%CI 9.1–17.8%); these developed within a median (Q1,Q3) of 2 days (1,3). (Table 2) In total, 72 patients developed 145 PUs. Of these, 39.3% (57/145, 95% CI 31.3–47.8%) were not related to devices; 16 (28.1%) were category 1, 17 (29.8%) category 2, 12 (21.1%) category 3 and 12 (21.1%) category 4. Two category 4 PUs were located on the occiput and developed in and around an existing wound area. 60.7% of the PU (88/145, 95% CI 52.2–68.7%) were related to devices. There were no category 4 PUs related to devices; 28 (31.8%)

Table 1. Baseline characteristics

	Value
Patient characteristics	**Median (Q1,Q3)/ Frequency (%)**
Age	52 (32, 65)
BMI[1]	26.6 (22.4,27.5)
Female	161 (63.4%)
Mechanism of injury	
Fall	106 (41.7%)
Cycle crash	52 (20.5%)
Car crash	40 (15.7 %)
Scooter	18 (7.1%)
Motorcycle crash	11 (4.3%)
Pedestrian struck	12 (4.7%)
Crush	10 (3.9%)
Assault	2 (0.8%)
Unknown	2 (0.8%)
Strangulation	1 (0.4%)
ISS score	
Mild (0-9)	89 (35%)
Moderate (10-15)	51 (20.1%)
Severe (16-24)	64 (25.2%)
Very severe (>24)	50 (19.7%)
Skin type**[2]	
Type 1-3 (Pale to light brown skin)	233 (91.6%)
Type 4-6 (Medium to very dark brown skin)	13 (5.1%)
Admission information	
Total LOS, days	5.0 (5,21)
LOS ED, minutes	213 (152,278)
LOS ICU, days (n=44)	4.5 (2,9)
LOS MCU, days (n=98)	2.0 (1,4)
LOS Ward, days (n=245)	4.0 (2,9)
	Mean, SD
Braden scale Total scores	15.9 (4.6)

Q1: first quartile, Q3: third quartile, SD: Standard Deviation, BMI: Body Mass Index, ISS: Injury Severity Score, LOS: Length of Stay, ED: Emergency Department, ICU: Intensive Care Unit, MCU: Medium Care Unit

[1]n=18 missing [2] n= 8 missing

**Following the Fitzpatrick scale Type 1: Very white skin, Type 2: White skin, Type 3: Cream white skin; Type 4: Brown skin; Type 5: Dark brown skin; Type 6:Black skin.

were category 1, 47 (53.4%) were category 2 and 13 (14.8%) were category 3. The majority (55.7%) of device-related PUs were related to immobilizing devices (49/88, 95% CI 44.7–66.3%), primarily the cervical collar (48/88). Of the device-related PUs, 44.3% (39/88, CI 33.7–55.3%) were related to medical devices, which were mainly restraints (19/88) and linen savers (6/88) (Table 3).

Locations

The PUs that were not related to devices were detected at six different locations and located on the back of the body, mainly on the buttocks (42.1%) and heels (33.4%). The device-related PUs were detected in 16 different regions on the front and back of the body. These PUs were mainly located on the chin (18.2%), back (14.8%), elbows (14.8%) and occiput (10.2%). (Figure 2)

Table 2. Pressure ulcer characteristics

Pressure ulcers	Values	95% Confidence Interval**
Incidence* (%)		
Overall pressure ulcers	28.3% (72/254)	22.8% - 34.3%
Device-related pressure ulcers	20.1% (51/254)	15.3% - 25.5%
Device-related Pressure ulcers only	13% (33/254)	9.1% - 17.8%
First observation pressure ulcers		
Days (mean)	3 (1,5)	
Within 1st week	63 (87.5%)	
Within 2nd week	8 (11.1%)	
3rd week or further	1 (1.4%)	
First observation device-related pressure ulcers		
Days (median, Q1,Q3)	2 (1,3)	
Within 1st week	32 (97%)	
Within 2nd week	1 (3%)	
3rd week or further	0	

Q1: first quartile, Q3: third quartile

*Incidence: % patients

** Clopper-Pearson exact method

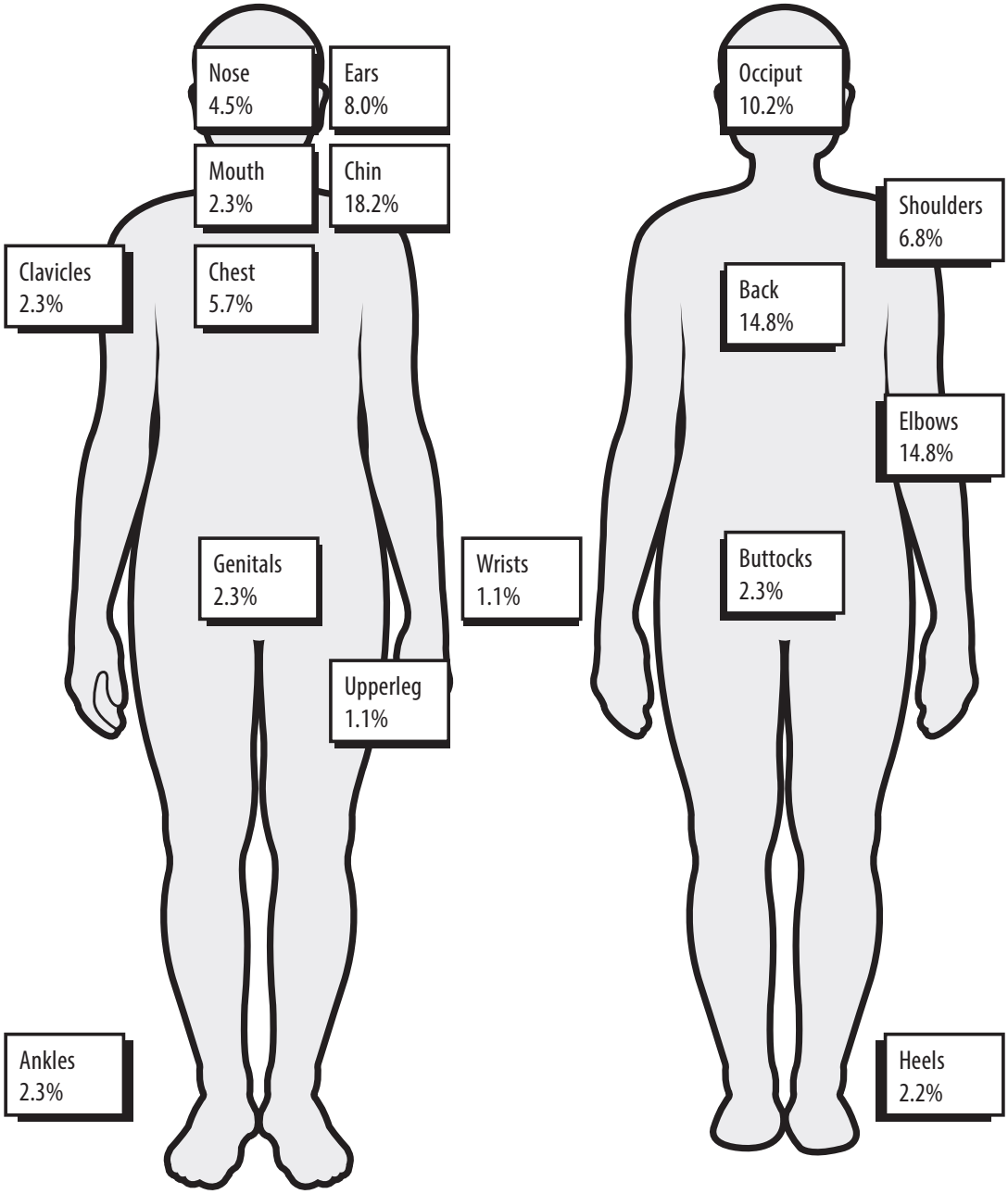
Table 3. Proportion of device-related pressure ulcers

95% confidence interval**	Values	
Total # Pressure ulcers	145	
Proportion pressure ulcers	57/145 (39.3%)	31.3%-47.8%
Proportion device-related pressure ulcers	88/145 (60.7%)	52.2%-68.7%
Immobilizing devices	49/88 (55.7%)	44.7%-66.3%
Medical Devices	39/88 (44.3%)	33.7%-55.3%

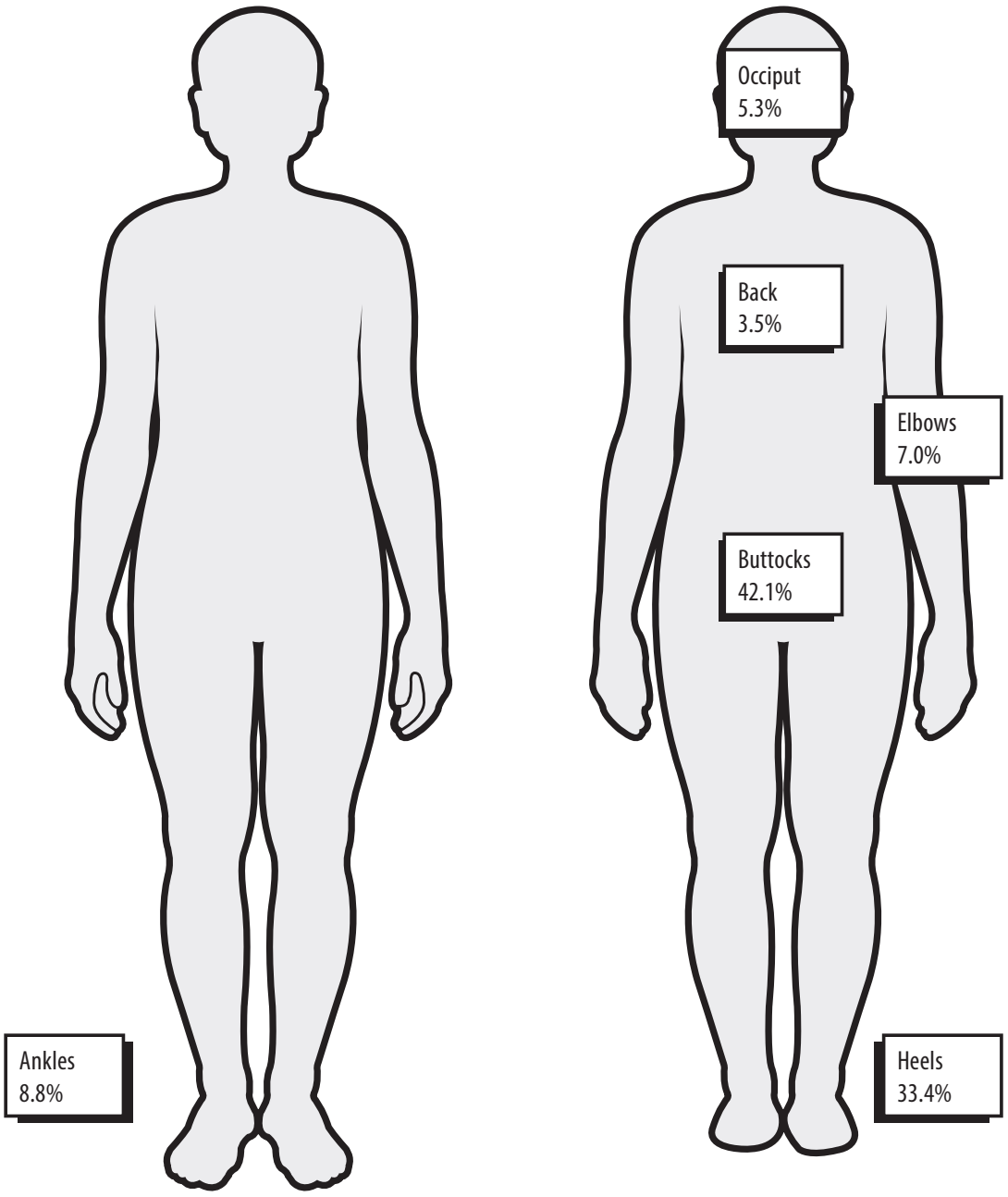
		Pressure ulcer categories			
	Total	**1**	**2**	**3**	**4**
Immobilizing devices (49)					
Cervical collar	48	20	27	1	-
HALO-vest	1	-	1	-	-
Medical devices (39)					
Urinary tubes	3	-	2	1	-
Endotracheal tubes	2	1	1	-	-
Nasogastric tubes	3	-	1	2	-
Cooling mattress	2	2	-	-	-
Restrains (wrist/ankles)	19	1	11	7	-
Oxygen tube	1	1	-	-	-
Linen saver	6	1	3	2	-
Endotracheal tube fixation	3	3	-	-	-

** Clopper-Pearson exact method

Figure 2. Pressure Ulcer locations



Device-related pressure ulcers (88)



Pressure ulcers not related to devices (57)

Discussion

Discussion of results

It is clear that trauma patients have a high risk of developing PUs. The overall PU incidence in our study sample is very high, 28.3%. This is in line with findings from 1998, describing a PU incidence of 30.6% (9). PU incidence rates in acute care settings from January 2000 to 2013 varied between 2.8% and 9% (category1–4) (4). These are notably lower incidences compared to our outcomes and indicate that within the acute care setting, trauma patients are more vulnerable to PU development. Undeniably, the application of devices generated high risk for PU development in our sample of trauma patients. Of the found PUs, 60.7% are related to devices. Furthermore, in 13% of our trauma patients, the PUs were solely related to devices. The exact figures are difficult to compare as studies on device-related PUs in trauma patients are scarce. In a prevalence study with 2079 hospitalized patients in intensive care, medical, surgical and step-down units, Black et al. found a device-related PU prevalence of 1.3% and a device-related PU proportion of 34.5% (8). Considering these findings, our results may indicate that trauma patients who were immobilized because of suspected spinal cord injuries prior to hospitalization are more vulnerable to device-related PU development. The international PU guideline describes device-related PUs as a 'pressure ulcer that results from the use of devices designed and applied for diagnostic or therapeutic purposes. The resultant PU generally closely conforms to the pattern or shape of the device' (4). We found that device-related PUs were mainly located on the back and front of the body. This was contrary to non-device-related PUs, which were solely located on the back of the body. The majority of the device-related PUs in our study corresponded to the pattern or shape of the device. However, we found PUs on the elbows, not following the pattern of shape of a device. These PUs were likely indirectly related to medical devices, wrist restraints. Most of these (indirectly) device-related PUs were category 2 or 3. The wrist restraints prevented movement in agitated and confused patients. Although movement of the wrists was restricted, the urge to move remained in most of these patients. The urge to move while in wrist restraints exposed elbows to pressure and shearing forces, which led to 'derived' device-related PUs. Contrary to our results, two studies on device-related PUs in hospitalized patients found category 4 PUs (8,19). We did not find any category 4 device-related PU; in fact, the majority of the device-related PUs were superficial, category 1 or 2. The fact that most device-related PUs were not a category 3 or 4 PU may be explained by the adherence to preventive protocols. First, in our study, sedated ICU patients with suspected cervical spine injuries were not immobilized with a Philadelphia® collar but with straps and lateral head supports. These high-risk patients were, therefore, not exposed to pressure from the collar while sedated. The Philadelphia® collar was applied only after the sedation had

stopped. This procedure literally minimized the time in the collar and, thus, the risk of PU development. Second, standard PU prevention protocols were applied. These protocols prescribed daily skin care and application of cotton stockings underneath the Philadelphia® collar for moisture absorption in order to optimize skin condition. If redness or PUs occurred, the standard procedure was to adjust the collar where possible to relieve pressure. These nursing protocols decreased the risk of PU development. Despite these preventive measures, we did find superficial device-related PU, which implies that the PU risk was not completely overcome. One explanation may be the fact that microclimate plays an important role in the development of superficial PUs. In (skin-covering) devices like collars, restraints and linen savers, the skin underneath may become moist and warm, which influences the microclimate (4,8). This enhances superficial PU development. Another explanation is the fact that devices may produce more shear forces, likely combined with friction, than pressure forces, leading to superficial PUs. This highlights the ongoing debate on whether high shear forces may primarily cause superficial ulcers while high-pressure forces may cause deeper ulcers (4). Frequent repositioning should be applied to inactive or immobile patients at risk in order to relieve pressure (20-22). This may be difficult to apply in trauma patients because of spinal injuries, bone fractures or hemodynamic instability (23) and may be complicated for several reasons. First, it may be prohibited because of specific injuries or treatment. Pain or fear to move as a result of the injuries may hinder repositioning. Second, in case of a (possible) spinal injury, straight alignment of the spine should be maintained. In these circumstances, patients are turned as a single unit while maintaining the straight alignment of the spine by a minimum of four trained caretakers, the logroll procedure (6). After logrolling, the patient is immediately placed back into the supine position; as a result, pressure relief will be achieved for a short period of time only. Moreover, the risk of causing neurological damage to the spine while logrolling might deter caretakers from performing the logroll procedure on a frequent basis. Most of the PUs in our study developed during the first days of admission. A logical explanation for the early PU development may be the severity of illness during the first days of admission, which is typical for trauma patients who are admitted as a result of traumatic injury. The severity of illness interacts with surgical interventions, malnutrition, ICU admission and immobility, which are all known risk factors for PU development (4,5). Another explanation for early PU development is the impact of pre-hospital immobilization with a backboard. As skin observation started after hospital admission and not in the emergency department, the exact relationship between immobilization and early PU development remains unclear. However, the fact that PUs were already seen on day 1 after admission may imply a causal relationship. Moreover, backboards are known to produce high interface pressures, (10,24,25) which may be sufficient for causing tissue damage in severely injured patients because of a decreased tissue tolerance (4,5). A

final explanation for early PU development is the emergency department stay, which may increase PU risk. After arrival in the emergency department, patients were left in extrication collars and headblocks in the supine position until the (cervical) spine was cleared. Patients were in the emergency department for a median of 213 minutes, on a stretcher (Stryker®, Amsterdam, The Netherlands) with small and thin mattresses. These trolleys are designed for easy transportation and radiation transmission and not to prevent PU development.

Strengths and limitations

This is the first observational study on PU development in trauma patients with a focus on PUs related to medical or immobilizing devices. PUs were observed by skin assessments during admission and not from documentation in patient records. This enhances the reliability of data collection and prevents the under-estimation of the problem because of incomplete registration. Furthermore, a single data collector performed data collection. This strengthened the reliability of data collection because no inter-rater reliability issues arose. Furthermore, expert consultation was used to reach consensus in PU classification. Eligible patients were admitted to the emergency department 24/7. In order to avoid incomplete sampling, delayed informed consent was authorized and applied. We strived to obtain a homogeneous sample by restricting the population and including solely trauma patients who were immobilized prior to hospitalization. To achieve realistic incidence figures, care-as-usual (risk assessment, prevention and PU care) was maintained during the study period. If patients developed a PU of category 2 or more, nurses were notified to pay extra attention to PU care. A possible limitation, however, may be the frequency of data collection. To assure both feasibility and continuity, data was collected within 24 hours and every 2 days thereafter by one data collector. Although category 1 PUs could have been missed because of this frequency, observing once every 48 hours ensured we did not miss the more severe PUs where the skin is broken (category 2 and above) as these would still have been visible as a scab when healing. Furthermore, our data showed that the majority of PUs developed during the first days of hospital admission. As we visited all patients within the first 48 hours of their hospital stay, and most patients were seen at least twice, the probability of detecting the PU was high. Results of our study may further be influenced by the Hawthorn effect. Nurses were present during data collection as this took place during daily care routines. Therefore, they were informed about the study purposes and were aware of skin inspections. This may have increased awareness of PU risk assessment and prevention. This was a single-center study; a multi-center study would have increased generalizability.

Conclusion

In conclusion, the incidence of PUs and device-related PUs in trauma patients who were immobilized because of suspected spinal injuries prior to hospital admission is high. Device-related PUs accounted for the majority of the PUs found and were located at various locations on the back and front of the body. PU risk appeared to be substantial in trauma patients. In order to prevent PU development in these high-risk patients, future research should focus on predictive risk factors for PU development and the application of effective and feasible preventive interventions.

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Chapter 7

Pressure Ulcer Development in Trauma patients with Suspected Spinal Injury; the Influence of Risk Factors Present in the Emergency Department.

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Abstract

Objectives

To explore the influence of risk factors present at emergency department admission on pressure ulcer development in trauma patients with suspected spinal injury, admitted to the hospital for evaluation and treatment of acute traumatic injuries.

Design

Prospective cohort

Study Setting

Level one trauma center in the Netherlands

Participants

Adult trauma patients transported to the emergency department on a backboard, with extrication collar and headblocks and admitted to the hospital for treatment or evaluation of their injuries.

Methods

Between January and December 2013, 254 trauma patients were included. The following dependent variables were collected: Age, Skin color and Body Mass Index, and Time in Emergency Department, Injury Severity Score, Mean Arterial Pressure, hemoglobin level, Glasgow Coma Score, and admission ward after emergency department.

Results

Pressure ulcer development during admission was associated with a higher age (p 0.00, OR 1.05) and a lower Glasgow Coma Scale score (p 0.00 , OR 1.21) and higher Injury Severity Scores (p 0.03, OR 1.05). Extra nutrition decreases the probability of PU development during admission (p 0.047, OR 0.194). Pressure ulcer development within the first 48 hours of admission was positively associated with a higher age (p 0.010, OR 1.030) and a lower Glasgow Coma Scale score (p 0.047, OR 1.142). The proportion of patients admitted to the intensive care unit and medium care unit was higher in patients with PU.

Conclusions

The pressure ulcer risk during admission is high in patients with an increased age, lower Glasgow Coma Scale and higher Injury Severity Score in the emergency department. Pressure ulcer risk should be assessed in the emergency department to apply preventive interventions in time.

Introduction

In the international pressure ulcer (PU) guideline, a PU is defined as 'localized injury to the skin and/or underlying tissue, usually over a bony prominence, resulting from sustained pressure (including pressure associated with shear).'(1). It is clear that a PU results from pressure, but not all patients exposed to pressure develop PUs. The tissue response on mechanical load (pressure) varies for each individual and multiple risk factors appear to play a role in PU development (1). Trauma patients may have a particular risk for developing PUs too. A specific high-risk group are trauma patients with suspected spinal injury. These patients are immobilized at the scene of accident, with a backboard, cervical collar and headblocks. Immobilization ends after evaluation in the emergency department (ED) and continues in case of diagnosed injury. Furthermore, their injuries can lead to prolonged periods of immobility and reduced perfusion and oxygenation. Above that, they are frequently exposed to immobilizing and medical devices. Following the most recent European Pressure Ulcer Advisory panel (EPUAP) guideline, adult patients with devices should be considered at risk for PU development (1). And third, all trauma patients are admitted to an emergency department, which increases PU risk (2,3).

The evidence to substantiate the increased PU risk in trauma patients is sparse. There are three studies (> 15 years) that describe the occurrence and risk factors for PUs in trauma patients (4-6). One retrospective study described a PU incidence of 0.4% in 7492 trauma patients (6) and two prospective studies described a PU incidence of 30.6% in 36 severe trauma patients, (4) and a PU prevalence of 20.3% in 148 trauma patients (5). Length of admission (4) and limitation in mobility (4,5) were described as possible risk factors for PU development in trauma patients.

We systematically reviewed 13 other studies specifically on PU development from immobilizing devices in trauma patients with suspected spinal (cord) injury. Of these, nine studies included healthy volunteers and only four studies included trauma patients. The latter described PU development specifically related to cervical collars (7). Collar-related PU incidence is described as 6.8 to 38% in two retrospective (8,9) and two prospective studies (10,11). Length of time in the collar, (8-11) admission to the Intensive Care Unit (ICU) and mechanical ventilation (11) were described as significant risk factors for collar related PU.

In contrast to the paucity of studies on risk factors for PU development in trauma patients, there are multiple studies on risk factors for pressure ulcer development within other patient populations. In a systematic review, Coleman et al. (2013) included 54 studies with a wide range of study populations, variables and methodologies (12). After evaluation of the study quality, the risk factors were described under twelve domains: 'impaired activity/mobility', 'skin status', 'perfusion and oxygenation', 'nutritional

status', 'skin moisture', 'body temperature', 'advanced age', 'sensory perception', 'hematological measures', 'general health status', 'gender' and 'race' (1,12). Of these, 'impaired activity/mobility', 'skin status' (presence of pressure ulcers), and 'perfusion and oxygenation' are considered major risk factors (1,12).

These risk factors are applicable for a wide range of patients, but it is, however, unclear to what extent these risk factors are applicable for the specific population of trauma patients with suspected spinal injury. These trauma patients are usually relatively young. Furthermore, they are generally healthy and well-nourished prior to admission and the mean age is notably lower compared to other risk groups (elderly, chronically ill). Risk factors for PU development in trauma patients with suspected spinal injury should therefore be assessed in order to identify patients vulnerable to PU development during hospital admission. We expect the PU risk to be at its highest in the acute phase; during ED stay and first days of admission. In the acute phase, injuries are recent and acute treatment is needed; this may lead to immobility and a decreased general health status. The identification of trauma patients at risk should start from admission to the ED, before hospitalization. Accordingly, appropriate preventive interventions can be applied in an early stage (1). The aim of this study was to explore the influence of risk factors present at ED admission on PU development in trauma patients with suspected spinal injury, admitted to the hospital for evaluation and treatment of acute traumatic injuries.

Methods

Design, setting and participants

Between January and December 2013, we conducted a prospective cohort study in a level one trauma center in The Netherlands. All consecutive trauma patients transported to the emergency department on a backboard, with extrication collar and headblocks, were eligible for participation. Inclusion criteria were: 1 trauma patients aged ≥ 18 years; 2 standard prehospital spinal immobilization (i.e. backboard, headblocks and extrication collar); 3 admitted to the hospital through the ED for treatment of acute traumatic injuries. Exclusion criteria were: 1 existing skin breakdown before admission; 2 severe burn wounds (>10% body region); 3 transferred from the emergency department to another hospital.

Immobilization procedure

In the ED, the backboard was removed directly after arrival in the crash room, before the initial assessment (13). Trauma patients remained immobilized, with an extrication collar and headblocks and in supine position. Injury of the spine was excluded or diagnosed by radiology (Computed Tomography scans) in combination with clinical examination. In intoxicated, unconscious or sedated patients, clinical examination was postponed until

patients restored consciousness. Meanwhile, the extrication collar and headblocks were replaced by a semi-rigid collar (Philadelphia® Philadelphia cervical collar co, NJ). In case of deep sedation (and thus not moving independently) and admission to the Intensive Care Unit, the cervical spine was immobilized with straps on the forehead and lateral support.

Study outcomes

Pressure ulcers

Pressure ulcer incidence comprised the number of patients that developed pressure ulcer(s) during their hospital stay. Because we expect the PU risk to be at its highest during ED stay and first days of admission, the number of patients with 'early' PUs development (within 48 hours after ED admission) was also described. Pressure ulcers were categorised using the International Pressure Ulcer Classification System (14). If redness was identified, a transparent disc was pressed onto the redness. If the skin under the transparent disk did not blanch, it was considered to be a category 1 PU (15).

Potential Risk Factors

To explore the association of potential risk factors with pressure ulcer development, the following variables were collected: Age, Skin color and Body Mass Index (BMI), and Time in ED, Injury Severity Score (ISS), Mean Arterial Pressure (MAP), hemoglobin level (Hb), Glasgow Coma Scale score (GCS), and admission ward after ED. ISS is a scale to measure injury severity, (16) and GCS is a scale to measure the level of consciousness (17). All potential risk factors were based on ten out of the twelve domains as described by Coleman et al. (2015) and the international PU guidelines (1,12).

Preventive interventions during admission

To adjust for possible confounders, we collected data on the application of preventive interventions. Preventive interventions were: application of a Pressure Redistributing (PR) mattress, frequent repositioning in bed, and extra Nutrition. The application of preventive interventions was scored until PUs were identified. If no PUs appeared, preventive interventions were scored until discharge or death.

All hospitalized patients were on a standard PR mattress. If nurses identified pressure ulcer risk or discovered pressure ulcers, patients were placed on the appropriate dynamic air mattresses (Promatt ®, or Auto Sure Float®). During an intensive care unit (ICU) stay, all patients were on a high-risk dynamic air mattress; next to pressure distributing functions, these mattresses were equipped with mechanisms to achieve various body-positions.

If patients were bed-bound, they were repositioned in bed at least every 2-4 hours per 8 hour shift. Repositioning in bed was not possible in case of hemodynamic instability,

instable fractures or increased pain due to movement of limbs. Institutional guidelines prescribed to screen all patients for malnutrition (Malnutrition Universal Screening Tool) (18). In case of risk for malnutrition, appropriate dietary interventions were taken.

Data collection

After primary survey in the ED, eligible trauma patients or their legal representatives were informed with written and verbal information. Informed consent was requested within 48 hours after admission (deferred consent). After inclusion, patients were followed up until discharge from the hospital or death. If a pressure ulcer was detected, the course of development was monitored. A nurse scientist, specialized and trained in PU care, collected data on a structured data collection form. Data on risk factors were collected on ED admission (day 0). Patient visits started at day one after hospital admission (at the latest within 48 hours), every two days, until PU development, discharge or death. All patient visits were planned during daily care routines, to minimize the burden for the patients. At each patient visit, a skin assessment for pressure ulcer development was performed. To assess the application of frequent repositioning (at least every 2-4 hours) and extra nutrition, nursing notes were examined, combined with observations during patient visits. The use of pressure-redistributing mattresses was observed ('dynamic air mattresses' and 'high- risk dynamic air mattresses') during patient visits.

Missing data

In 33 patients, 34 values were randomly missing (1.03%) on BMI, MAP and Hb. In order to include these patients in the analysis, we performed multiple imputation in five iterations on all missing data (linear regression model). Means of the imputed variables were comparable to the original data. (Table 1)

Analysis

PU incidence was defined as a proportion: the number of patients who developed at least 1 category 1-4 pressure ulcer within the total sample. We constructed 95% confidence intervals (CIs) around proportions (Clopper-Pearson exact method) (19). Baseline characteristics were described as frequencies and percentages for categorical or dichotomous variables. As continuous data were not normally distributed, the median and the inter quartile range (first Q1, third quartile Q3) were described. The two-sided Mann-Whitney test and chi-square test were used to compare risk factors in patients with and without PUs. In order to explore the association between risk factors for PU development, multivariate analysis using logistic regression was performed (enter method). The associations between potential risk factors and PU development during admission were described. As we expect the risk to be highest during ED stay and the first days of admission, the association between potential risk factors and

Table 1. Missing data

Values	# missing values	Original mean values	Imputed mean values
BMI	18	25.6	25.6
MAP	6	79.6	79.7
HB	2	8.5	8.5
		Original data 1-3 4-6	Imputed data 1-3 4-6
Skin color**	8	233 13	240 14

BMI: Body Mass Index; MAP: Mean Arterial Pressure HB: Haemoglobin**Following the Fitzpatrick scale Type 1: Very white skin, Type 2: White skin, Type 3: Cream white skin; Type 4: Brown skin; Type 5: Dark brown skin; Type 6: Black skin.

PU development within 48 hours was also described. There was no indication for multicollinearity between potential risk factors. The level of significance was established at $p < 0.05$. We used the Statistical Package for the Social Sciences (SPSS) 20.0 program for data description and analysis (Version 20.0, Armonk, NY: IBM Corp.).

Results

During the study in 2013, 623 trauma patients were admitted to the emergency department with suspected spinal injury. Of these, 244 were discharged from the ED, 10 died in the emergency department, and 22 patients were discharged before consent. 347 were assessed for eligibility. Based on exclusion criteria 21 were excluded and 36 refused participation. Finally, 290 patients were recruited for the study. 36 patients were lost to follow up during the study. Ultimately, 254 trauma patients were included for analysis. (Figure 1)

Baseline characteristics

The median (Q1,Q3) age was 52 (32,65) years and 93 (36.6%) were female. Mechanisms of injury were mainly falls (n=106, 41.7%), followed by cycle crashes (n=52, 20.5%) and car crashes (n=40, 15.7%). In our sample, 140 patients suffered a mild to moderate injury (35% ISS 0-9 and 20.1% ISS 10-15). 114 patients were severely to very severely injured (25.2% ISS 16-24 and 19.7% ISS >24). Median time (Q1,Q3) in the emergency department was 213 (152, 278) minutes and patients were hospitalized for a median (Q1,Q3) of 5.0 (5,21) days. 44 patients were admitted to the ICU and 98 to the Medium Care Unit. The majority of the patients had a 'pale to light brown' skin pigmentation (n=233, 91.6%).

Pressure Ulcer Incidence

The incidence of PU development during the period of hospital stay was 28.3% (72/254; CI 95% 22.9-34.3%); The incidence of pressure ulcer development within 48 hours after admission was 13% (33/254; CI 95% 9.1%-17.8%).

Group Comparison

In both patients groups (PU development during admission or PU development within 48 hours) patients with PU had a significant higher age, and a significant lower MAP, Hemoglobin level and GCS score. Type of admission ward differed significantly between patients with and without PU; the proportion of patients admitted to the Intensive Care unit and Medium Care Unit was higher in patients with PU. (Table 2)

Multivariate logistic regression

PU development during admission was associated with a higher age (p 0.00, OR 1.05) and a lower GCS score (p 0.00 , OR 1.21) and higher ISS Scores (p 0.03, OR 1.05). Extra nutrition was negatively associated with PU development during admission (p 0.047, OR 0.194). PU development within the first 48 hours of admission was positively associated with a higher age (p 0.010, OR 1.030) and a lower GCS score (p 0.047, OR 1.142). (Table 3)

Figure 1. Flowchart inclusion

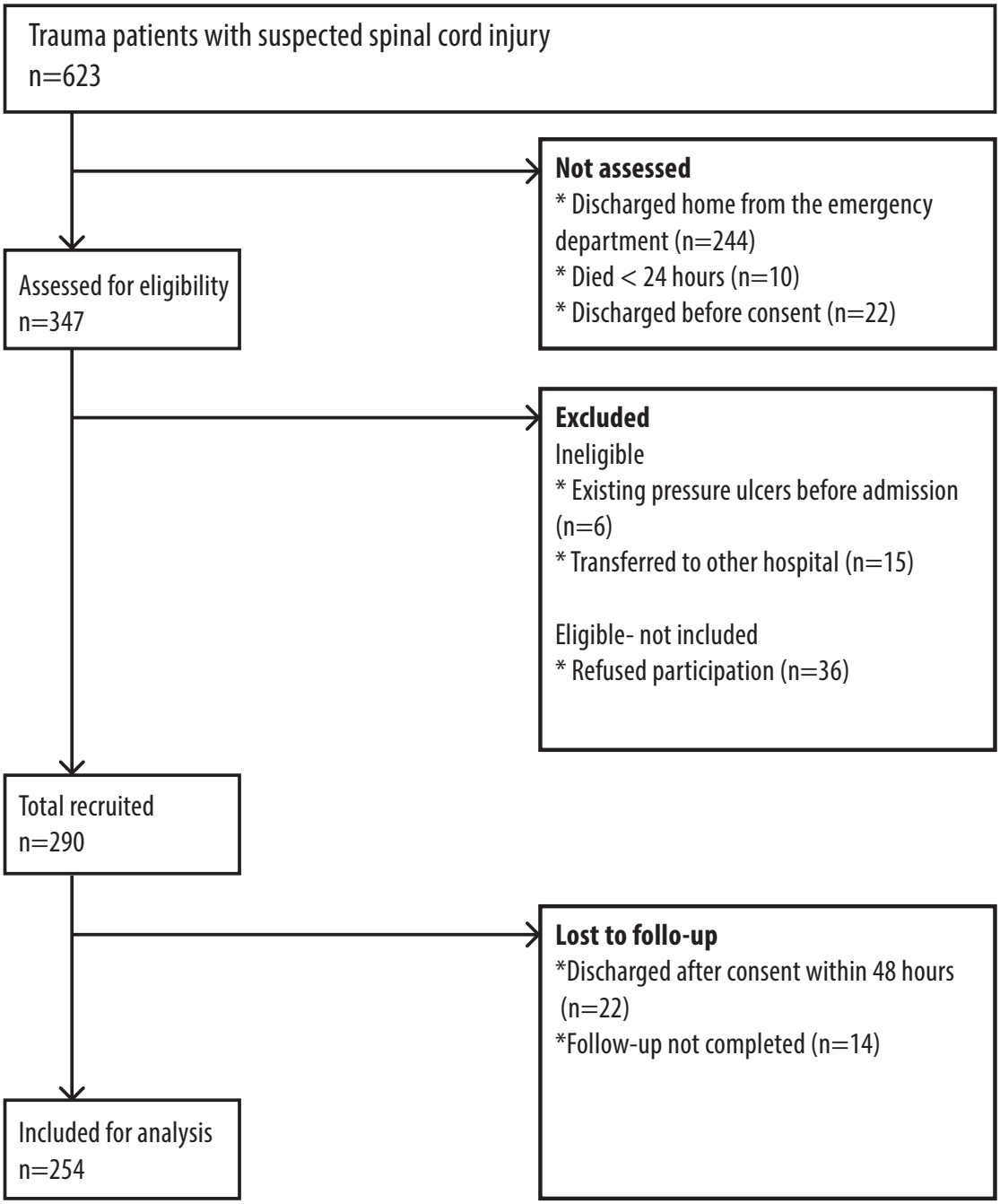

Table 2. Group comparisons

	Pressure ulcer development during admission			**Pressure ulcer development within 48 hours**		
	No n=182	Yes n=72	Mann-Whitney U	No n=222	Yes n=33	Mann-Whitney U
	Mean rank score			*Mean rank score*		
Age	111.4	168.3	Z[1] -5.56 p 0.00	120.9	171.7	Z -3.71 p 0.00
BMI	129.7	121.8	Z -0.8 p 0.42	127.1	130.4	Z -0.22 p 0.83
Length in ED	131.0	118.6	Z – 1.21 p 0.23	127.1	130.1	Z -0.22 p 0.83
ISS	114.8	159.6	Z -4.39 p 0.00	125.1	143.9	Z- 1.37 P 0.17
MAP	135.0	108.6	Z -2.58 p 0.00	131.1	103.7	Z -1.99 P 0.05
HB	139.7	96.7	Z -4.21 p 0.00	131.7	103.7	Z – 2.33 p 0.02
GCS	113.0	164.2	Z -5.88 p 0.00	124.0	99.6	Z-2.33 p 0.02
	No n	Yes	Chi-square	No n	Yes	Chi-square
Gender						
Male	114	47	Chi²0.2	138	23	Chi 0.65
Female	68	25	p 0.4	83	10	p 0.42
Skin**						
Light	173	67	Chi 0.37	210	30	Chi 0.93
Dark	9	5	p 0.53	11	3	P 0.33
Admission						
ICU	13	31	Chi 55.5	33	11	Chi 10.05
MCU	44	22	P 0.00	55	11	P 0.00
Ward	125	19		133	11	

BMI: Body Mass Index; ED: Emergency Department; ISS: Injury Severity Score; MAP: Mean Arterial Pressure HB: Haemoglobin; GCS Glasgow Coma Scale; **Following the Fitzpatrick scale Light: Type 1-Type 3, Dark: Type 4 -Type 6

Table 3. Multivariate logistic regression (enter method)

Pressure ulcer development during admission n = 72				Pressure Ulcer development within 48 h n = 33		
	P value	*OR*	*95% CI*	*P value*	*OR*	*95% CI*
Age	0.00*	1.05	1.03-1.07	0.01*	1.03	1.01-1.06
Female[1]	0.17	1.74	0.79-3.88	0.25	1.71	0.69-4.21
Skin color**[2]	0.64	0.71	0.17-2.96	0.28	0.44	0.10-1.97
BMI	0.66	0.98	0.91-1.06	0.93	1.00	0.91-1.09
Length in ED	0.41	1.00	1.00-1.01	0.74	1.00	1.00-1.01
ISS	0.03*	1.05	1.00-1.09	0.76	1.01	0.96-1.05
MAP	0.11	0.98	0.98-0.96	0.13	0.98	0.96-1.01
HB	0.27	0.82	0.57-1.17	0.42	0.87	0.61-1.23
GCS	0.00*	1.21	1.08-1.35	0.01*	1.16	1.03-1.31
Position change[3]	0.34	4.50	0.21-96.53	0.33	0.26	0.02-3.84
Extra nutrition[4]	0.04*	0.20	0.04-0.94	0.87	1.13	0.25-5.19
PR mattress[5]	0.68	0.79	0.26-2.37	0.81	1.17	0.33-4.09

**Following the Fitzpatrick scale Light: Type 1-Type 3, Dark: Type 4 -Type 6; BMI: Body Mass Index; ED: Emergency Department; ISS: Injury Severity Score; MAP: Mean Arterial Pressure HB: Haemoglobin; GCS: Glasgow Coma Scale; PR; Pressure Redistributing.

[1] Reference: Female [2] Reference: Dark pigmentation [3] Reference: no position change [4] Reference: No extra nutrition [5] Reference: no PR Mattress

Discussion

This was an explorative study on risk factors in trauma patients with suspected spinal injury. We found that patients who developed PU, had a significantly higher age, and a significantly lower MAP, Hemoglobin level and GCS score in the ED. Furthermore, we found a significant difference in type of admission ward after evaluation in the ED in patients with PU. PU development during admission was positively associated with a higher age, low GCS and a higher ISS in the ED. PU development within 48 hours was positively associated with higher age and a low GCS in the ED.

In contrast to ISS, GCS, hb level and MAP, age is a non-influenceable risk factor, and not related to the severity of injury. Age is a known risk factor for PU development, (1,12) and apparently also significantly associated with PU development in this relatively young group of patients. ISS, GCS, Hb level and MAP are risk factors that are all directly related to the patients' condition. Type of admission ward is also obviously related to the patient's conditions as the complexity of required care corresponds with the type of admission ward.

Trauma has a major physical and mental impact on a patient's and their caregivers' life. PU development during the admission will increase this impact, and can easily delay rehabilitation (20,21). Emergency nurses, trauma surgeons and emergency physicians should recognize the increased PU risk in trauma patients who have been immobilized for preventive reasons. It is of utmost importance to be aware of the increased pressure ulcer risk in the advanced aged trauma patients and trauma patients in a critical condition. Specifically, low GCS and the severity of injury should be considered in evaluating the PU risk in the ED. In our study, we evaluated the association between risk factors present at ED admission and PU development, as we expected the PU risk to be at its highest during ED stay and first days of admission. In total, 28.3% of the trauma patients developed PUs. Of these 45.8% of the patients developed PUs within 48 hours after admission and 54.2% of the trauma patients developed PUs after 48 hours of admission. All patients were immobilized with a backboard prior to emergency department admission, which increased the PU risk (7,22,23). Although the backboard was removed after arrival in the crash room, trauma patients remained immobilized with an extrication collar and headblocks and in supine position on a Stryker ® stretcher, until spinal injury was diagnosed or excluded. These stretchers are equipped with small and thin mattresses, which are easy manageable and designed for radiation transmission. The period of immobilization, both on the backboard and on the stretcher, increased the PU risk.

In our study, 'extra nutrition' decreased the probability of PU development during admission. Clearly the regular screening, nutrition assessment and the application of a nutrition plan in trauma patients have contributed to a significantly decreased probability

of developing PUs. Malnutrition is a known risk factor for PU development (1,24-27). In general, unlike the elderly, (1,24) trauma patients are most likely well- nourished prior to hospital admission, as they are relative young and healthy, but, malnutrition during admission may form a risk for trauma patients; it is likely that the nutritional needs increase due to their injuries, and their nutritional supply may be delayed due to surgical procedures or medical tests.

Emergency nurses should initiate the application of a PU prevention plan before ward admission. As emergency nurses are involved in direct patient care day-and-night they should emphasize the importance of a timely risk assessment, and increase awareness of the PU risk in these patients.

Furthermore, we need to realize that two major preventive interventions for pressure ulcer development, namely "repositioning" and "early mobilization", may be hindered in this patient group due to their injuries. As a consequence, regular skin assessment should be intensified to help detect pressure ulcer risk in an early phase, in order to apply alternative preventive interventions, when "repositioning" or "early mobilization" is impossible.

Strengths and limitations

This is the first explorative study on risk factors present in the ED and PU development in trauma patients. The actual association between risk factors present at ED admission and PU development during admission may be biased by risk factors that occurred during admission. We did not evaluate the association between risk factors that occurred during hospital admission and PU development; therefore it is well possible that other risk factors play a role in PU development during admission.

Eligible patients were admitted to the ED day-and-night. In order to avoid selection bias, delayed informed consent was authorized and applied. A homogeneous sample was obtained by restriction; solely trauma patients who were immobilized with a backboard, extrication collar and headblocks prior to hospitalization were included. To attain realistic incidence figures, care-as-usual (risk assessment, prevention and PU care) was maintained during the study period. If patients developed a PU category 2 or more, nurses were notified to pay extra attention to pressure ulcer care.

The presence of PUs was observed by skin assessments and not extracted from patient records. Data collection by skin observations strengthens reliability and prevents under evaluation due to incomplete documentation. The reliability of data-collection was further improved, since a single data collector performed data collection; no inter-rater reliability issues arose.

Data was collected within 24 hours, and every 2 days thereafter by one data-collector. Although category 1 pressure ulcers could have been missed due to this frequency, observing once every 48 hours ensured we did not miss category 2 to 4 PUs, as these

were still visible as a scab when healing. We visited all patients within the first 48 hours of their hospital stay, and most patients were seen at least twice. Therefore, the probability of detecting a PU was high.

Results of our study may however be influenced by the Hawthorn effect. Nurses were informed and aware of skin inspections for study purposes, since this took place during daily care routines. This may have increased awareness of PU risk assessment and prevention.

Implications for practice and further research

After evaluation in the crash room of the ED, medical and nursing staff should be aware of the increased PU risk for trauma patients immobilized with a backboard, cervical collar and headblocks prior to hospital admission. Furthermore, trauma patients with increased age, a low GCS score, and high ISS scotres, are at risk for PU development. Preventive interventions should be initiated and applied in an early stage of admission. Nurses should recognize the fact that frequent repositioning is a challenge in trauma patients. If frequent repositioning is not possible, patients should be considered at risk and skin assessments and the prevention program should be intensified.

Future studies should focus on prevention of pressure ulcers in this specific patient group, in order to develop effective preventive interventions. Further research is needed to explore risk factors for PU development during the hospital stay.

Conclusions

PU risk should be assessed in the ED to apply preventive interventions in time. We explored the influence of risk factors on PU development in trauma patients with suspected spinal injury, who were immobilized with a backboard, headblocks and cervical collar prior to evaluation in the ED. The PU risk during admission is high in patients with an increased age, lower GCS and higher ISS score in the ED.

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Chapter 8

General Discussion
Pressure Ulcers in trauma patients with preventive spinal immobilization; current evidence and the future perspectives

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Submitted

Introduction

One of the primary goals in the initial management of a trauma patient is to identify the presence of possible spinal injury. In patients with suspected spinal injury, spinal *cord* injury should be prevented. Therefore, all trauma patients with suspected spinal injury are (preventively) immobilized. The rationale behind preventive immobilization is that spinal *cord* injury may develop or worsen from displacement of spinal fractures due to movement. Prevention of spinal cord injury can be literally life-saving, as spinal cord injury can lead to impairment of high cervical nerves, which innervate breathing.

After the trauma has occurred, prevention of spinal cord injury starts at the scene of accident. Consistent with their protocols, paramedics will decide if preventive spinal immobilization is indicated. Until recently, the following immobilizing devices have been advocated to immobilize the spine: the backboard, extrication collar and lateral headblocks (1,2). After arrival in the emergency department, the patients will be evaluated for their injuries, and, if necessary, proper treatment is started. The backboard should be used as an extrication and transportation device by paramedics; and therefore be removed after arrival in the emergency department (3,4); patients remain in supine position, in the extrication collar and headblocks. Until spinal injury is excluded or diagnosed and treated, patients are prohibited to turn or move. The period from the scene of accident, evaluation in the emergency department, until exclusion or diagnosis of spinal injury, is the acute phase. During this phase, trauma patients remain immobilized for *preventive reasons.* After this phase, immobilization for preventive reasons ends, but continues in case of diagnosed injury. This is referred to as the follow-up phase.

'Do no further harm'

The prevention of spinal cord injury is a well-intended and common procedure in trauma care. Although this procedure may be potentially lifesaving, spinal immobilization can cause unintended effects. It is therefore of utmost importance to apply the 'do no further harm' principle. This principle should lead to a thorough evaluation of the impact of spinal immobilization, whereas unintended effects should be weighed against the intended effects of spinal immobilization. First, immobilization complicates endotracheal intubation as the design of the extrication collar hinders complete mouth opening (5-7). Second, practice shows that patients have an increased risk for aspiration of the gastric content, because patients may not be able to clear their own airway in case of vomiting (7-9). Comprehensive protocols prescribe instructions of logrolling in case of vomiting, so that the vomit can drain away from the airway (1,2,10). Third, the pressure of the extrication collar and headblocks may lead to an increased intracranial pressure, because jugular veins may be compressed (11,12). In case of neurological

damage, this may worsen the outcome, whereas the blood supply is hindered. And last, the pressure from the backboard and extrication collar and headblocks on the skin, may lead to pain and pressure ulcer development (13,14).

Pressure ulcer risk

This paper focusses on the development of pressure ulcers in trauma patients with suspected spinal injury. Pressure ulcers are defined as 'localized injury to the skin and/or underlying tissue, usually over a bony prominence, resulting from *sustained pressure* (including pressure associated with shear).'(15). There are two phases in the care trajectory of trauma patients in which we can identify a risk for pressure ulcer development. First, in the acute phase, when patients with suspected spinal injury are evaluated in the emergency department. In this phase, *sustained pressure and shear forces* are generated by the immobilizing devices (backboard, extrication collar and headblocks), and patients are prohibited to turn or move until spinal injury is excluded or diagnosed. The second phase is the follow-up period after evaluation in the emergency department, when patients are admitted to the hospital. The period of immobilization in the acute phase may be crucial for pressure ulcer development in the follow-up period, as pressure ulcers may occur within one to six hours after sustained pressure and shearing forces (16). Also, in case of diagnosed spinal injury, sustained pressure and shear forces remain present through prolonged spinal immobilization therapy or the application of long-term immobilizing devices like semi-rigid collars, HALO-frames, or external fixation. Moreover, when spinal immobilization is discontinued after exclusion of spinal injury, pressure ulcer risk remains present, as several conditions typical for trauma patients may sustain this risk. First, injuries other than spinal injury can lead to extended periods of immobilization. Fractures of the pelvic bones or costal bones are typical injuries that minimize or hinder proper mobilization. Second, severely injured trauma patients are likely to be exposed to other risk factors for pressure ulcer development. Their injuries may lead to decreased sensation; direct tissue damage; decreased dermal perfusion due to hypovolemic shock; altered nutrition; and surgical interventions. All of these conditions are known to increase pressure ulcer risk (15,17). And third, trauma patients remain largely exposed to both immobilizing as well as medical devices. This increases pressure ulcer risk remarkably, thus patients with devices should be considered at risk for pressure ulcer development (15,17-21).

In this paper we present an overview of the current evidence regarding pressure ulcer development in trauma patients with suspected spinal cord injury. We focus on the development of pressure ulcers as an unintended adverse effect of spinal immobilization in the acute phase, and the risk of pressure ulcer development in this specific group of patients in the follow-up phase, with an emphasis on device-related pressure ulcers. Based on this overview we describe recommendations for further research and nursing practice.

Current evidence

We performed a systematic literature review (22) in which we included 13 studies. Nine experimental studies included healthy volunteers and only four clinical studies included trauma patients. The clinical studies described the incidence of pressure ulcers related to cervical collars, which ranged from 6.8 to 38%. The severity of these pressure ulcers ranged from category 1 to 4, and they were typically located on the occiput, chin, shoulders, and back. Furthermore, these studies described the following preventive interventions: "early replacement of the extrication collar by semi-rigid cervical collar", "regular skin assessment", "collar refit" and "position change" (23-26). Nine experimental studies demonstrated high pressure ulcer risk from the cervical collar and backboards on healthy volunteers due to increased tissue oxygenation, skin humidity, skin temperature, and high tissue interface pressures (27-35). Furthermore, five of the experimental studies described increased pain/discomfort from the cervical collars and backboards. Pain and discomfort were significantly higher when pressures from devices where high (28-30,32,35). Our literature study showed that pressure ulcers from immobilizing devices in trauma patients are a very relevant problem, although the magnitude of the problem in terms of incidence, characteristics, risk factors and preventive strategies needs further investigation. There is a paucity of knowledge on pressure ulcer development from immobilizing devices in trauma patients. We did not find any clinical studies that addressed the risk for pressure ulcers in trauma patients related to immobilizing devices such as backboards, or cervical collars combined with headblocks and straps. Neither did we find studies that explored the effect of preventive interventions on pressure ulcer development from devices. These findings provided the basis for prospective studies. In these studies, we focused on two phases of the clinical pathway of trauma patients with suspected spinal injury. The first prospective study focused on the acute phase- evaluation in the emergency department, and the second prospective study on follow-up phase- hospital admission for treatment of the injuries.

Acute phase- Emergency department

In the first prospective study, 342 trauma patients were included in the acute phase. All trauma patients were immobilized with an extrication collar and headblocks, until spinal injury was excluded or diagnosed. The occurrence, characteristics and risk factors of pressure ulcer related to the extrication collar and headblocks were evaluated by emergency nurses. In addition to pressure ulcers, we assessed the presence of indentation marks and pain from the extrication collar and headblocks. (36) We added these outcomes, because emergency nurses reported pain in trauma patients, due to the application of an extrication collar and headblocks. Additionally, they observed profound indentation marks from the extrication collar and headblocks after removal.

Pain and indentation marks may demonstrate the extreme discomfort related to the extrication collar and headblocks. Furthermore, pain from immobilizing devices has been described in experimental studies (22).

Before the start of the prospective study, emergency nurses were tested and trained to identify and classify pressure ulcers from photos (37). Accurate identification improved significantly from 87.7 % to 95.6 % (p = 0.000) and classification skills improved significantly from 68.5 % to 84.1 % (p=0.000). The multi-rater Kappa for identification increased from 0.63 to 0.82 and the multi-rater Kappa for classification increased from 0.43 to 0.58. During the study, the trained emergency nurses used handouts with descriptions and illustrations of pressure ulcer wounds corresponding to the categories. We found a mean of 2.5 pressure ulcers per patient, related to the extrication collar and headblocks. The overall incidence was very high, namely 78.4% (95%CI: 73.6-82.6%) (36). The majority (75.4%) had a category 1 and only 2.9% had a category 2 pressure ulcer. The incidence of indentation marks was 64.6% (n=221, 95%CI: 59.3-69.7%) of which 43.4% of the patients (n=96) suffered from severe indentation marks. All indentation marks followed the pattern of the extrication collar. The incidence of pain (NRS >3) was 63.2% (n=182, 95% CI: 57.3-68.8%) of which 61.0% (n=111) experienced severe pain (NRS 7-10). Severe pain occurred most frequently at the occiput (160 times). Time in the extrication collar and headblocks, patient characteristics, and injury severity was not significantly associated with pressure ulcer development or indentation marks from the extrication collar and headblocks. We did find a significant higher Body Mass Index in patients with indentation marks (z -1.9, p 0.05), compared to patients without indentation marks. Furthermore, females were significantly more likely to experience pain (OR 2.14, p 0.009) from the extrication collar and headblocks, compared to males.

Follow-up phase-hospital admission

In the second phase we focused on trauma patients who were admitted to the hospital, after evaluation in the emergency department. At this stage, spinal injury has already been excluded or diagnosed, for the majority of patients. We aimed to investigate pressure ulcer occurrence, characteristics (38) and risk factors (39) in trauma patients hospitalized for treatment of their traumatic injuries. Furthermore, we focused on the occurrence and characteristics of device-related pressure ulcers, and the proportion of the pressure ulcers related to devices. We identified pressure ulcers related to medical devices (endotracheal tubes, oxygen masks, nasogastric tubes, urinary tubes, thromboembolic stockings, linen savers-cotton woven blankets used as repositioning aid or mattress protector-, or restraints) and immobilizing devices (cervical collars, casts, splints, external fixation, or HALO-frames). Lastly, we described preventive interventions that were applied to prevent pressure ulcer development. We included 254 trauma patients who were hospitalized after evaluation in the emergency department. (38)

We identified 72 patients (28.3%, 95% CI 22.8%-34.3%) who developed a total of 145 pressure ulcers. Of these, 60.7% (88/145, 95% CI 52.2%-68.7%) were related to devices. 87.5% of the pressure ulcers were observed within the first week of admission, as they developed after a median (Q1,Q3) of 3.0 (1,5) days. We identified higher proportions of category 1 (31.8% vs. 28.1%) and 2 (53.4% vs. 29.8%) pressure ulcers in device-related pressure ulcers, but higher proportions of category 3 (21.1% vs. 14.8%) and 4 (21.1% vs. zero) in pressure ulcer that were not related to devices. The majority (55.7%) of device-related pressure ulcers were related to *immobilizing* devices (49/88, 95% CI 44.7%-66.3%), primarily the cervical collar (54.5%). 44.3% (39/88, CI 33.7%-55.3%) of the device-related pressure ulcers were related to *medical* devices, which were mainly restraints (21.6%) and linen savers (6.8%). The device-related pressure ulcers were detected in 16 regions on the front and back of the body, mainly the chin (18.2%), back (14.8%), elbows (14.8%) and occiput (10.2%). Pressure ulcers that were not related to devices were located on the back of the body, mainly on the buttocks (42.1%) and heels (33.4%).

In a second analysis we explored the influence of risk factors present on pressure ulcer development (39). Because identification of trauma patients at risk should start in the acute phase, and before hospitalization, insight in these risk factors is fundamental. Therefore, we explored risk factors that were present in the emergency department. As we expected the pressure ulcer risk to vary between the acute and follow-up phase, we explored the influence of risk factors on 'early' pressure ulcer development (within 48 hours after emergency department admission) as well as the influence on pressure ulcer development during admission.

Age, mean arterial pressure, Glasgow Coma Scale and hemoglobin level were significantly different between patients with and without both 'early' pressure ulcer development as well as pressure ulcer development during admission. Injury Severity Scores differed significantly between patients with and without pressure ulcer development during admission. We found a positive association between age (p 0.02, OR 1.030) and Glasgow Coma score (p 0.047, OR 1.142) and early pressure ulcer development and between age (OR 1.05, p 0.00), Injury Severity Score (OR 1.05, p 0.03) and GCS score (OR 1.21, p 0.00) and pressure ulcer development during admission. Extra nutrition was negatively associated with pressure ulcer development during admission (OR 0.79, p 0.04).

Preventive interventions

During the acute phase, no preventive interventions were applied. All patients were on a standard trolley. The mattresses are designed for radiation transmission and not to prevent pressure ulcer development. All patients are kept sober in the emergency department and skin assessment started after hospital admission.

During the follow-up phase, all patients were on a hospital-wide used standard pressure-reducing mattress. If pressure ulcer risk or pressure ulcers were identified, patients were placed on the appropriate dynamic air mattresses (Promatt ®, or Auto Sure Float ®). All patients were on a high-risk dynamic air mattress during Intensive Care Unit stay; next to pressure distributing functions, these beds are designed to enhance early mobilization. If patients were bedfast or immobile, they were repositioned at least every 2-4 hours per 8-hour shift. If patients were hemodynamically instable, diagnosed with instable fractures or experienced increased pain due to movement of limbs, repositioning was not possible Malnutrition was screened in all patients according to the institutional guidelines (Malnutrition Universal Screening Tool) (40). In case of risk for malnutrition, appropriate dietary interventions were taken.

Discussion

In trauma patients with suspected spinal injury, there is a serious risk for pressure ulcer development. This risk occurs during from the scene of accident to evaluation in the emergency department (acute phase) as well as during hospital admission (follow-up phase).

Acute phase

In the acute phase, the vast majority of trauma patients developed pressure ulcers as well as indentation marks from the extrication collar and headblocks (36). The majority of the pressure ulcers identified was category 1. Although reversible in most patients, this indicates an increased risk for development of a more severe pressure ulcer (41,42). The severe indentation marks (including tumor and rubor), may be an inflammatory reaction and thus a first sign of tissue damage (18,43). Especially in case of long-term collar treatment, this may lead to pressure ulceration. Most patients experienced pain from the extrication collar and headblocks, and 40 % experienced severe pain. Pain can bias clinical evaluation of the cervical spine, which results in lengthy immobilization. Above that, practice demonstrates that severe pain creates unrest and an impulse to move, in order to relieve the pressure. This is potentially dangerous, as in case of injury, the consequences of movement may be catastrophic. (2,44,45)

We were the first to evaluate unintended effects of spinal immobilization in trauma patients in the *acute phase*. This, however, is only a small part of a substantial problem; more insight in other unintended effects is therefore necessary. First, we solely evaluated pressure ulcers and pain from the extrication collar and headblocks, but did not evaluate unintended effects from the backboard. Second, there is a paucity of sound scientific evidence on unintended effects of preventive spinal immobilization in the acute phase. Some studies describe the possible relationship between increased intracranial pressure

and compression of jugular veins by the extrication collar, (11,12) however, more research to substantiate this relationship is needed. There are no clinical studies or case reports on risk for aspiration of the gastric content, nor on complications during airway management related to the extrication collar, while in practice this is a commonly seen problem. Next to these unintended physical effects, spinal immobilization may lead to physiological distress or anxiety, but again, scientific evidence is lacking.

Currently, spinal immobilization in the acute phase is under debate. This debate is rooted in the uncertainty of the intended effect, as well as the unintended effects of spinal immobilization. Different opinions are advocated by authors from varying disciplines involved in trauma care: traumatology, emergency medicine, prehospital care, neurosurgery and orthopaedics. All authors state that the current procedure of preventive immobilization should be reviewed and that more research is needed. Some authors propose to continue preventive immobilization as before while gathering evidence to validate adjustments of the current protocol (45-51). Others advocate to adjust the current protocol of spinal immobilization, in order to decrease the unintended effects (52-62). The debate regarding preventive spinal immobilization is tremendously challenging and complicated due to the lack of sound scientific evidence.

Although only 2-4% of the patients suffers from actual spinal (cord) injury, (61) we should not throw the baby out with the bathwater by simply mimimizing the application of spinal immobilization in trauma patients with suspected spinal injury.

Immobilization has become controversial as there are no clinical trials that confirm the intended effect of spinal immobilization (49-51,63). The absence of these studies however, cannot justify the doubts about the intended effect of spinal immobilization. Performing a clinical trial is simply not possible on ethical grounds. Therefore, the intended effect is unambiguous as the rationale behind spinal immobilization, namely ‘movement in case of fractures can worsen injury’, appears plausible. Above that, we know that immobilization is the only conventional and suitable treatment in case of diagnosed spinal injury (45). Therefore, preventive immobilization should be continued until safe alternatives have been introduced.

We do need to be very specific and cautious in the application of spinal immobilization for preventive reasons. This awareness should lead to scientifically substantiated decisions or adaptations in our spinal immobilization protocol. The increased awareness of unintended effects has led to selective application of preventive spinal immobilization in prehospital care. And although selective application is vital, a validated uniform prehospital decision rule is lacking, (62) and multiple varying decision rules are applied in different states and countries (64). This may lead to obscurity and miscommunication, and even more, patients with actual spinal cord injury may be missed.

Another response to the increased awareness of unintended effects is the application of different types of spinal immobilization techniques. In the Netherlands, immobilization

techniques have been shifted from “backboard, extrication collar combined with headblocks”, towards “vacuum mattresses”, “scoop stretchers”, “backboards”, “different types of head immobilizers”, “manual stabilization instead of a cervical collar”, “cervical collars”, “headblocks”, or a combination of various techniques (65). Although these initiatives are aimed at reducing the unintended effects of preventive spinal immobilization in the acute phase, it is highly questionable to what extent these changes are based on sound scientific evidence (47). Again, we should not throw the baby out with the bathwater. Nevertheless, we urgently need to evaluate the current practice of preventive spinal immobilization. First, collaborative programs should be established in order to reach consensus in developing a validated and uniform decision rule, as well as standard spinal immobilization techniques. More research is needed to substantiate our decisions and modifications. To guarantee continuity of care, collaboration should be extended to all partners engaged in the acute phase, including pre-hospital and emergency department caretakers (45,47,62,66).

Meanwhile, it is extremely important to evaluate and revise the current immobilizing materials and devices, in order to decrease unintended effects, like pressure ulcers, indentation marks and pain. Where trauma patients used to be immobilized on a backboard for prolonged periods of time, the current view is to remove the backboard after arrival in the emergency department (2,3,62). This insight is based on the fact that backboards increase the pressure ulcer risk. Currently, the industry anticipates on the ongoing debate; several new immobilizing devices have been developed. We need to carefully select and implement validated and tested devices, in order to safely immobilize trauma patients.

Based on our study results, we developed an alternative device for immobilization with the extrication collar and headblocks. We modified the design of the device and used pressure distributing materials, in order to decrease the risk for pressure ulcers, indentation marks and pain. Next to a decrease of unintended effects, this device is designed to preserve the primary purpose: immobilization of the spine. Extensive validation tests are required before utilization in practice.

Follow-up phase

During the *follow-up* phase, 28.3% of the trauma patients developed pressure ulcers during their hospital stay. Furthermore, the majority of pressure ulcers were related to devices (60.7 %) (38). Pressure ulcers are a physical, financial and mental weight to patients and their relatives. Pressure ulcers have a major impact on the quality of life, morbidity, mortality, and rehabilitation (67-70). We should recognize the pressure ulcer risk in trauma patients who have been immobilized from the scene of accident. Our study results did not provide direct evidence of a relationship between the period of spinal immobilization in the acute phase and pressure ulcer development in the

follow-up phase. Spinal immobilization however, may well play a role in pressure ulcer risk during hospital stay. A parallel may be drawn with the pressure ulcer risk in "patients undergoing surgery". Although these patients are unable to relieve pressure or reposition due to anesthetics, they are also immobilized for prolonged periods and positioned on relatively hard surfaces. It is assumed that immobility during (and throughout) the surgical procedure is associated with pressure ulcer development during admission (15,71,72).

Trauma patients are a relatively young and healthy population, and may therefore not be considered at risk for pressure ulcer development. In response to our study results however, we should create awareness of the high pressure ulcer risk in the formerly immobilized trauma patients who are admitted to the hospital, in all caretakers involved in trauma care. Nurses can be in the forefront of creating this awareness, as they are involved in direct patient care day-and-night. During both acute and follow-up phase, nurses should emphasize the importance of a timely risk assessment, and increase awareness of negative effects from (preventive) interventions.

Risk assessment should start in the emergency department. From the moment an immobilized trauma patient is assessed and evaluated in the emergency department, we need to realize that there is a pressure ulcer risk. This risk increases with an increase of injury severity (Injury Severity Score) and age, and a decrease of consciousness (Glasgow Coma Scale) (39). Therefore, we should prioritize preventive interventions and apply them in an early stage. Furthermore, we need to realize that two major preventive interventions for pressure ulcer development, namely "repositioning" and "early mobilization", may be hindered in this patient group due to their injuries (73). As a consequence, regular skin assessment should be intensified to help detect pressure ulcer risk in an early phase, in order to apply alternative preventive interventions, when "repositioning" or "early mobilization" is impossible.

To increase awareness of negative effects, prevention programs towards pressure ulcers from devices should be extended. The international pressure ulcer guidelines describe clear preventive strategies (15). We should determine if devices could be (temporarily) removed or regularly repositioned, if medically feasible. Second, if patients have devices, we should ensure the proper fit and sizing. Furthermore, the skin underneath the devices should be regularly inspected and kept dry. Prophylactic dressing to protect the skin should be considered (74).

Research in the acute and emergency care is challenging. First, emergency care is acute, not predictable and is provided day-and-night. For this reason, data collection is challenging and labor-intensive. Second, research in the field of emergency care is susceptible to selection bias. If the emergency department is overcrowded, standard patient care has to be prioritized over patient inclusion or data collection. In our studies, overcrowding has lead to a relatively large proportion of missed patients (36). Although

research is challenging, this should not keep us from initiating research in the acute care setting. There is an urgent need for sound scientific evidence in the emergency and acute care. Emergency nurses can play an important role in the scientification of acute and emergency care. They are the acute care experts and the driving force of the emergency department, as they are directly and continuously involved in the patient flow and patient care. Therefore, they are sensitive to significant problems or shortcomings in the acute care setting. We need to recognize the importance of scientific evidence to substantiate our treatment and protocols. Because gaining evidence is a great challenge, type of evidence should be weighed against the efforts needed to achieve evidence. Therefore, not only clinical trials, but also case reports or observational studies can provide extremely important data. In the light of our study results, future studies should be aimed at the acute phase, as well as the follow-up phase. In the acute phase, research should address the development and validation of a uniform prehospital decision rule for spinal immobilization. This decision rule should lead to a safe, structured and careful selection of patients with suspected spinal injury. Furthermore, we should develop, test and evaluate new and existing immobilizing devices or combinations of devices. This should lead to uniform protocols and immobilization techniques throughout the care trajectory in the acute phase.

During the follow-up phase, future research should focus on pressure ulcer risk in trauma patients. Our studies form a base for further research to establish alternative, yet effective preventive programs, if "repositioning" or "early immobilization" is impossible or hindered.

And last, we were the first to describe indentation marks in patients from direct pressure to the skin. Future studies should explore the physiological characteristics and the possible relationship with pressure ulcer development.

Conclusions

The fundaments of trauma care are based on survival, and although this is a primary aim, we need to prevent "further harm" or unintended effects of our treatment, along the way to survival. Our study results show that trauma patients who are immobilized in case of suspected spinal injury, are at risk for pressure ulcer development, during both the acute as well as the follow-up phase. Nursing and medical staff needs to be aware of this increased risk, in order to intervene in an early phase and to prevent pressure ulcer development. We should prioritize the discussion on spinal immobilization in order to revise the practice. And in the end, the current method of spinal immobilization should be revised; stepwise, cautious and careful; and not until we have established safe alternatives.

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Chapter 9

Summary

Samenvatting

Dankwoord

Curriculum Vitae

To protect the (possibly) injured spine, trauma patients are immobilized on a backboard, with an extrication collar, lateral headblocks, and straps. Although pressure ulcers are typically associated with older adults and chronic illness, of all patients in a hospital environment, these trauma patients may be particularly at risk for developing (device-related) pressure ulcers. Pressure ulcers are a serious health complication that develop as a result of pressure alone or pressure in combination with shear force.

Trauma patients (with suspected spinal injury) have traumatic injuries, are immobile, and exposed to immobilizing and medical devices; these are all factors that increase the risk to develop pressure ulcers.

In **Chapter 1** we briefly describe the history of trauma care and the rationale behind preventive spinal immobilization in trauma patients. The thesis focuses primarily on the development of pressure ulcers in trauma patients with suspected spinal injury. We defined general research questions that served as a fundament for our studies:

- What is the incidence of pressure ulcers in trauma patients, immobilized with a backboard, extrication collar and headblocks due to suspected spinal injury?
- Which risk factors play a role in pressure ulcer development in trauma patients with suspected spinal injury?

In **Chapter 2** we describe a systematic review on pressure ulcers, as a complication of immobilization of the spine with existing immobilizing devices. With this review we aimed to gain insight in the occurrence and severity, risk factors, and possible interventions to prevent pressure ulcers related to spinal immobilization with devices in adult trauma patients. We included 13 studies. The majority of these studies (nine), included healthy volunteers under spinal immobilization. Only four studies included trauma patients under preventive spinal immobilization. The results of the latter studies show an incidence of collar-related pressure ulcers ranging from 6.8% to 38%. Described locations are the occiput, chin, shoulders, and back. The severity of these pressure ulcers varied between category 1 and 3, and one study described pressure ulcers requiring surgical debridement, indicating a category 4 pressure ulcer. The risk factors for pressure ulcer development are ‘high pressure’ and ‘pain’ from immobilizing devices in healthy volunteers. In trauma patients, the length of time in/on a device, intensive care unit admission, high Injury Severity Scores, mechanical ventilation, and intracranial pressure monitoring were described as risk factors. Preventive interventions for collar-related pressure ulcers comprised early replacement of the extrication collar and regular skin assessment, collar refit, and position change. We did not find any studies that described the occurrence of pressure ulcers in trauma patients related to the application of spinal immobilization devices such as backboards, vacuum mattresses or headblocks. The results from this systematic review

showed that preventive immobilization with devices increased the risk for pressure ulcer development.

In **Chapter 3** we describe an experimental study on pressure ulcer identification and classification skills of emergency nurses and emergency physicians. With this study, we evaluated the short-term effect of an educational intervention. Pressure ulcers were identified and classified from photos. A one-group pretest/posttest design was used to test the skills and interrater reliability (multirater kappa) before and after an educational intervention. The educational intervention comprised a workshop that consisted of a lecture based on the Pressure Ulcer Classification (PUCLAS2) educational tool. The lecture included basic information and definitions, with examples and illustrations of pressure ulcer causes, characteristics, and classifications. We included 54 emergency nurses and physicians. Accurate identification improved significantly from 87.7% to 95.6%, and classification skills improved significantly from 68.5% to 79.8%. The multirater kappa for identification of pressure ulcers increased from 0.63 to 0.82, and the multirater kappa for classification of pressure ulcers rose from 0.43 to 0.58. The most frequently misclassified photographs were those that displayed category 1, 2, and 3 pressure ulcers, which were usually classified as more severe. Identifying the presence of a pressure ulcer in a photograph was less challenging than categorizing the wound.

In **Chapter 4** we describe an observational study conducted in the emergency department of a level one trauma center. In this study, we included 342 adult trauma patients in an extrication collar combined with headblocks. We assessed the occurrence and severity of pressure ulcers, indentation marks and pain from the extrication collar combined with headblocks. Furthermore, the influence of time, injury severity and patient characteristics on the development of pressure ulcers, indentation marks and pain was explored. We found that 75.4% of the trauma patients developed a category 1 and 2.9% a category 2 pressure ulcer. Indentation marks were observed in 221 (64.6%) patients; 96 (28.1%) had severe indentation marks. Pressure ulcers and indentation marks were observed most frequently at the back, shoulders and chest. 63.2% experienced pain, of which 38.5% experienced severe pain. Pain was mainly located at the occiput. Body Mass Index was significantly different between patients with and without indentation marks. None of the investigated variables significantly increased the probability of developing pressure ulcers or indentation marks. Being a female significantly increased the likelihood of experiencing pain compared to being male. We concluded that the high incidences of pressure ulcers and indentation marks indicate an increased risk for pressure ulcer development due to the application of the extrication collar and headblocks. Pain from the extrication collar and headblocks may

lead to undesirable movement (in order to relieve the pressure). It is therefore necessary to revise the current practice of cervical spine immobilization.

In **Chapter 5** we describe a discussion paper in reaction to the latest version of the Dutch National Protocol Ambulance Care (Landelijk Protocol Ambulancezorg-LPA 8), which was officially introduced on January 1st 2015. One of the sub protocols: 'spinal immobilization' has been revised, but contains too few guarantees for the safety of trauma patients in whom preventive spinal immobilization has to be performed. A number of strict indications for immobilization were removed and too much flexibility was permitted concerning the implementation. Although the previous standard method using a spinal board, extrication collar and headblocks did have disadvantages, the revised protocol misses sound scientific founding and, in addition, is not well matched to the protocols of accident and emergency departments. It is vital that the agencies involved should collaborate to reach a joint solution. With this discussion paper we hope to initiate a discussion in order to support the development of safe and reliable trauma care throughout the entire chain of care.

Chapter 6 contains an observational study on incidence and characteristics of pressure ulcers in adult trauma patients. Furthermore, the proportion of pressure ulcers that are related to devices were described in this study. We performed a prospective cohort study and included 254 trauma patients, with preventive spinal immobilization prior to hospital admission. The overall incidence of pressure ulcers was 28.3%. The incidence of device-related pressure ulcers was 20.1%, and 13% developed solely device-related pressure ulcers. We observed 145 pressure ulcers in total of which 60.7% were related to devices. Device-related pressure ulcers were detected 16 different locations on the front and back of the body. These results show that the incidence of pressure ulcers and the proportion of device-related pressure ulcers is very high in trauma patients.

In **Chapter 7** we describe a study in which we explored the influence of risk factors present at emergency department admission on pressure ulcer development in a prospective cohort. We included 254 trauma patients with suspected spinal injury, admitted to the hospital for evaluation and treatment of acute traumatic injuries. We found that pressure ulcer development during admission was significantly associated with a higher age, a lower Glasgow Coma Scale score and higher Injury Severity Scores. Extra nutrition significantly decreased the probability of pressure ulcer development during admission. Pressure ulcer development within the first 48 hours of admission was significantly associated with a higher age, and a lower Glasgow Coma Scale score. The proportion of patients admitted to the intensive care unit and medium care unit was higher in patients who developed pressure ulcers.

In **Chapter 8** we describe the general discussion of this thesis. First, we present an overview of the evidence as described in **Chapter 2 – 7**, in which we distinguish between the acute phase (period from the scene of accident and evaluation in the emergency department, until exclusion or diagnosis of spinal injury) and the follow-up phase (spinal injury has been excluded or diagnosed). Second, we discuss this evidence in the light of the current discussion on preventive spinal immobilization, and the urgent needed change of practice and rationale behind preventive spinal immobilization to prevent pressure ulcer development in this specific group of patients. These changes are necessary for medical as well as nursing care. Finally we describe recommendations for practice and future studies, while stressing the importance of the expert role of nurses in scientification of the emergency and acute care.

Summary

Samenvatting

Dankwoord

Curriculum Vitae

In het geval van mogelijk wervelletsel, worden traumapatiënten geïmmobiliseerd op een harde plank, met een harde kraag en blokken. Deze schuimrubberen blokken worden aan de zijkanten van het gezicht geplaatst, zodat de patiënt het hoofd niet kan bewegen. Hoewel decubitus voornamelijk in verband wordt gebracht met ouderen en chronische zieken, kunnen traumapatiënten een bijzonder hoog risico voor het ontwikkelen van (materiaal-gerelateerde) decubitus hebben. Decubitus is een ernstig gezondheidsprobleem dat ontstaat als gevolg van drukkrachten of druk- gecombineerd met schuifkrachten. Deze traumapatiënten (met een verdenking op wervelletsel) hebben verwondingen, zijn immobiel, en er worden immobiliserende en medische materialen gebruikt voor de behandeling; allemaal zaken die dat risico op decubitus verhogen.

In **Hoofdstuk 1** beschrijven we de geschiedenis van de traumazorg en de achtergrond van preventieve immobilisatie bij traumapatiënten. De focus van dit proefschrift ligt op ontwikkeling van decubitus bij traumapatiënten met een verdenking op wervelkolomletsel. We definieerden algemene onderzoeksvragen, die leidend waren voor onze studies:

- Hoe vaak komt decubitus voor bij traumapatiënten die geïmmobiliseerd waren met een harde plank, een harde kraag en laterale blokken?
- Welke risicofactoren spelen een rol in de ontwikkeling van decubitus bij traumapatiënten die verdacht werden van wervelkolom letsel?

In **Hoofdstuk 2** beschrijven we een literatuurstudie naar decubitus, als complicatie van preventieve immobilisatie van de wervelkolom met immobiliserend materiaal. Denk hierbij aan de harde wervelplank, het vacuümmatras en de nekkraag. Met deze literatuurstudie wilden wij inzicht krijgen in het ontstaan, de ernst, de risicofactoren en de mogelijke interventies om decubitus te voorkomen. We vonden 13 studies. Het merendeel van deze studies (negen) onderzochten gezonde vrijwilligers waarbij de wervelkolom werd geïmmobiliseerd. Slechts vier studies onderzochten 'echte' traumapatiënten waarbij preventieve immobilisatie was toegepast met de nekkraag. Uit de resultaten van deze laatstgenoemde studies blijkt het vóórkomen van decubitus die veroorzaakt wordt door de nekkraag, te variëren tussen de 6,8% en 38%. De plekken waar deze decubitus ontstond waren het achterhoofd, kin, schouders en rug. De ernst van decubitus varieerde tussen categorie 1 en 3, en één studie beschrijft decubitus waarvoor 'chirurgisch ingrijpen' nodig was. Dat laatste kan wijzen op een categorie 4 decubitus wond. In de studies werd ook beschreven welke risicofactoren er zijn voor het ontstaan van decubitus. Bij de onderzoeken met gezonde vrijwilligers werden 'hoge druk' en 'pijn' gemeten. Bij de onderzoeken met traumapatiënten werden de volgende risicofactoren beschreven: de totale duur van immobiliseren, opname op de afdeling intensive care, ernstige verwondingen, beademing, en het meten van de hersendruk.

Interventies om decubitus (veroorzaakt door de nekkraag) te voorkomen waren: tijdige vervanging van de harde kraag voor een 'zachte' versie en regelmatige inspectie van de huid onder de kraag. Daarnaast werd het regelmatig aanpassen en herpositioneren van de nekkraag aanbevolen. Er werden geen studies gevonden die keken naar decubitus bij traumapatiënten die werd veroorzaakt door de harde plank, het vacuümmatras of de blokken. Uit de resultaten van onze literatuurstudie blijkt dat preventieve wervelkolom immobilisatie het risico op decubitus verhoogt.

In **Hoofdstuk 3** beschrijven we een studie waarin we hebben gemeten in hoeverre spoedeisende hulp verpleegkundigen en artsen decubitus correct konden herkennen en indelen in categorieën. Dit deden zij door foto's van decubitus te bekijken. Daarnaast keken we wat de overeenkomst was tussen de antwoorden van verpleegkundigen en artsen (interbeoordelaars betrouwbaarheid). Ook keken we in deze studie naar het korte termijn effect van een les over decubitus. We gebruikten een voor- en nameting om te testen of de verpleegkundigen en artsen decubitus beter herkenden en indeelden in categorieën na de les over decubitus. Deze les bestond uit een workshop, waarin informatie werd gegeven die gebaseerd was op het Decubitus Classification (PUCLAS2) e-learning pakket. De informatie bestond uit basiskennis en definities, met voorbeelden en foto's van oorzaken, kenmerken, en de categorieën 1-4 van decubitus. 54 spoedeisende hulp verpleegkundigen en artsen deden mee aan de studie. Na de les, verbeterden herkenning van decubitus significant (van 87,7% naar 95,6%), en de indeling in categorieën verbeterden ook significant, (van 68,5% correct naar 79,8% correct). De interbeoordelaars betrouwbaarheid voor de herkenning van decubitus steeg van 0,63 naar 0,82, en voor de indeling van decubitus steeg deze van 0,43 naar 0,58. Foto's met daarop een categorie 1, 2 en 3 decubituswond werden meestal als ernstiger ingedeeld. Het herkennen van de decubitus van een foto was gemakkelijker dan het indelen van een decubitus plek.

In **Hoofdstuk 4** beschrijven we een observationele studie die werd uitgevoerd op de afdeling spoedeisende hulp van een groot traumacentrum. In deze studie onderzochten we 342 volwassen traumapatiënten. Alle patiënten waren preventief geïmmobiliseerd met een harde kraag gecombineerd met blokken. We bestudeerden het vóórkomen en de ernst van decubitus, indentatieletsel en pijn door de harde kraag gecombineerd met blokken. Daarnaast werd onderzocht wat de invloed van de tijd, letsel ernst en patiëntkenmerken op de ontwikkeling van decubitus, indentatieletsel en pijn was. Indentatieletsel is de afdruk van de kraag in de huid, die achterblijft als de harde kraag is verwijderd. 75,4% van de traumapatiënten ontwikkelden een categorie 1 decubitus en 2,9% een categorie 2 decubitus. Indentatieletsel werd gezien bij 64,6% traumapatiënten; 28,1% had ernstige drukletsel. Decubitus en indentatieletsel werden

vaak gezien op de rug, schouders en de borst. 63,2% van de trauma patiënten hadden pijn, waarvan 38,5% ernstige pijn had. De pijn was vooral aanwezig op het achterhoofd. Geen van de onderzochte variabelen verhoogde de kans op het ontwikkelen decubitus of indentatieletsel significant. Wel hebben vrouwen meer kans op het ontwikkelen van pijn, ten opzichte van mannen. In deze studie concludeerden we dat de hoge percentages van decubitus en indentatieletsel aantoonden dat er een verhoogd risico op decubitus als gevolg van de toepassing van de harde kraag en blokken is. Pijn van de harde kraag en blokken kan leiden tot ongewenste beweging (om de druk te verminderen) of vertekening van het klinisch onderzoek van de cervicale wervelkolom. Daarom is het noodzakelijk om de manier waarop we nu de nekwervels immobiliseren (met harde nekkraag en blokken) aan te passen.

In **Hoofdstuk 5** beschrijven we een discussiestuk. Dit stuk hebben we geschreven als reactie op de nieuwste versie van het Nederlandse Nationaal Protocol Ambulancezorg (Landelijk Protocol Ambulancezorg LPA 8), die officieel werd ingevoerd op 1 januari 2015. Eén van de protocollen: 'wervelkolom immobilisatie' werd herzien. Echter, dit protocol waarborgt de veiligheid van traumapatiënten waarbij preventieve immobilisatie moet worden uitgevoerd onvoldoende. Een aantal strikte regels voor immobilisatie zijn verdwenen en er wordt teveel ruimte gelaten voor uitvoering van het protocol. Het oude protocol, waarbij standaard gebruik gemaakt werd van een harde plank, harde kraag en blokken had zeker nadelen, maar het nieuwe protocol mist een duidelijke wetenschappelijke onderbouwing. Daarnaast lijkt het niet goed afgestemd op de protocollen van spoedeisende hulp afdelingen. Het is essentieel dat alle betrokken partners samenwerken om tot een gezamenlijke oplossing te komen. Met dit discussiestuk hopen we het debat op gang te brengen om op die manier een bijdrage te leveren aan de ontwikkeling van veilige en betrouwbare traumazorg in de hele keten.

In **Hoofdstuk 6** beschrijven we een studie naar het vóórkomen en de kenmerken van decubitus bij volwassen traumapatiënten. Daarnaast beschrijven we in deze studie decubitus die wordt veroorzaakt door medisch of immobiliserend materiaal. We voerden een prospectieve cohort studie uit en onderzochten 254 traumapatiënten. Al deze patiënten werden geïmmobiliseerd voorafgaand aan de ziekenhuisopname, doordat ze verdacht werden van wervelkolom letsel. 28,3% van de patiënten ontwikkelden decubitus, en bij 20,1% was dit ook decubitus die werd veroorzaakt door materiaal. 13% van de patiënten ontwikkelden zelfs uitsluitend decubitus die veroorzaakt werd door materiaal. In totaal vonden we 145 decubitus plekken, waarvan 60,7% gerelateerd waren aan materiaal. Materiaal-gerelateerde decubitus werd op 16 verschillende plaatsen aan de voorkant en achterkant van het lichaam gedetecteerd. De resultaten uit

deze studie laten zien dat het vóórkomen van decubitus en het percentage materiaal-gerelateerde decubitus zeer hoog is bij traumapatiënten.

In **Hoofdstuk 7** beschrijven we een prospectieve cohort studie. In deze studie onderzochten we de invloed van risicofactoren (op de afdeling spoedeisende hulp) op de ontwikkeling van decubitus. We onderzochten 254 traumapatiënten met een verdenking op letsel aan de wervelkolom. Al deze patiënten werden opgenomen in het ziekenhuis voor evaluatie en behandeling van hun verwondingen. Decubitus die tijdens de opname ontstond was significant geassocieerd met een hogere leeftijd. Daarnaast was het ook geassocieerd met een lager bewustzijn (Glasgow Coma Score) en ernstige verwondingen (Injury Severity Scale), zoals gemeten op de afdeling spoedeisende hulp. Door bijvoeding te geven, daalde de kans het ontwikkelen van decubitus tijdens opname significant. Het ontwikkelen van decubitus binnen 48 uur na opname, was significant geassocieerd met een hogere leeftijd en een lager bewustzijn op de afdeling spoedeisende hulp. Het percentage patiënten dat opgenomen was op de intensive en medium care unit was hoger bij patiënten die decubitus ontwikkelden.

In **Hoofdstuk 8** beschrijven we de algemene discussie van dit proefschrift. Ten eerste presenteren we een overzicht van het verzamelde wetenschappelijke bewijs, zoals omschreven in de **Hoofdstukken 2-7**. Hierin maken we onderscheid tussen de acute fase (periode van de plaats van een ongeval, tot het moment dat wervelletsel is gediagnosticeerd of uitgesloten op de afdeling spoedeisende hulp) en de follow-up fase (wervelletsel is uitgesloten of gediagnosticeerd). Ten tweede bespreken we deze nieuwe inzichten in het licht van de huidige discussie over preventieve immobilisatie. Er is een dringende noodzaak voor verandering van zowel de praktijk als ‘de achterliggende gedachtes’ over preventieve wervelkolom immobilisatie, om de ontwikkeling van decubitus in deze specifieke groep patiënten te voorkomen. Deze veranderingen zijn noodzakelijk voor zowel de medische als de verpleegkundige zorg. Tenslotte doen we aanbevelingen voor de praktijk en toekomstige studies, waarbij we het belang van de deskundige rol van spoedeisende hulp verpleegkundigen voor de verwetenschappelijking van de acute- en spoedzorg benadrukken.

Summary

Samenvatting

Dankwoord

Curriculum Vitae

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Summary

Samenvatting

Dankwoord

Curriculum Vitae

Wietske Ham was born in the Hague, the Netherlands, in 1979. She attended the "Willem de Zwijger" secondary school in Schoonhoven. In 1997 she started her Bachelor of Nursing in Utrecht and did her traineeship at the st. Antonius hospital in Nieuwegein. In 2002, Wietske started as registered nurse at the department of cardio-thoracic surgery at the University Medical Center in Utrecht. She worked as a senior and medium care nurse for three years, after which she switched to the emergency department in 2005 and graduated as a certified emergency nurse soon after. In 2007 she started her Masters in Nursing Science at Utrecht University. She performed the study for her thesis in the Elmhurst Hospital in New York, on pressure ulcers from cervical collars in trauma patients admitted to the intensive care unit, and graduated in 2010. In 2012 she started her PhD on pressure ulcers in trauma patients. She combined the research activities with her work as an emergency nurse in the emergency department and lecturing in the premaster program of Clinical Health Science. Based on the results of one of the studies, she wanted to design an alternative device to immobilize the cervical spine. This device should replace the extrication collar combined with headblocks. She started a collaboration with the industrial designers of Pontes Medical. This collaboration lead to a new cervical immobilizing device: the FIXAID. With this device, they made it to the finals of the UREKA mega challenge of the University Medical Center in 2015. Wietske continues to work as an emergency nurse, combined with research activities for the Trauma Center of the University Medical Centre Utrecht.

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