

Current Risk Factors for Iatrogenic Pressure Injuries in Neonates

A Literature Review

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Abstract Even though 'never events' like hospital acquired (iatrogenic) pressure injuries (PI) in neonates exist, there is a paucity of evidence-based knowledge. Neonates and especially preterm newborns are at risk for skin breakdown due to their anatomic, physiologic and developmental characteristics. PI prevalences were reported to be >50%, causing pain, lengthy hospital stays, emotional and financial burden. It was aimed at determining current risk factors for iatrogenic PI's in neonates, to raise awareness on the issue among nurses and point out the need for further research on neonate-specific risk factor. Providing up-to-date knowledge and an impulse to create an efficient assessment tool to help nurses reduce iatrogenic pressure injuries in neonatal care settings was intended. Four databases (CINAHL, PubMed, Academic Search Elite and Google Scholar) were browsed to collect all relevant articles meeting the inclusion criteria. A qualitative content analysis was conducted to analyze the data found from 15 articles. After extraction, data was organized by formulating subcategories and finally abstracted to main, general categories. The following main categories of risk factors were created; medical devices, medical condition of the neonate, length of stay and care practice. The results of this review clearly showed the need for further research on risk factors underlying neonatal PIs. The increasing use of medical devices posed an evident threat though risk factors seem naturally interrelated. The existence of a coercible need for raising awareness among paediatric nurses on PI existence and continuous evidence-based education of nursing staff was recognized and the development of a specific assessment tool recommended.		
Keywords iatrogenic, pressure injury, neonatal, risk factors		
Miscellaneous		

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1. Introduction

A pressure injury (PI) can lengthen the hospital stay, increases the risk of sepsis, scarring and can even cause death (Vance, Demel, Kirksey, Moynihan & Hollis 2015, 156). Still, PIIs seem commonly neglected in neonatal care or perceived as a solely adult issue (Habiballah & Tubaishat 2016, 128; Peterson, Adlard, Walti, Hayakawa, McClean & Feidner 2015, 276). For adults, prevention and treatment of hospital-acquired (iatrogenic) injuries has been a nursing research priority for at least the past two decades, but there is a paucity of research among the neonatal patient population (Murray et al. 2013, 585). However, PIIs pose a significant threat to the vulnerable patient group of neonates (August, Edmonds, Brown, Murphy & Kandasamy 2013, 136; Schlüer, Halfens & Schols 2013, 3251). They cause suffering for the patient and their family in terms of pain, lengthy hospital stays, embarrassment due to permanent disfigurement and financial burden (Habiballah & Tubaishat, 2016, 128).

Iatrogenic PIIs are by definition acquired during the hospital stay and are identified as never events. This meaning they will not be reimbursed by public funds because they are considered preventable (van Gilder, Amlung, Harrison & Meyer 2009, 39; Centers for Medicare and Medicaid Services, 2006). Results though show that 50-85% of iatrogenic PIIs are preventable (Matthew, Scanlon, Mitchell, Fiona 2008, 1723; Garcia-Molina & Balaguer-Lopez 2014, 151). The financial costs for these events are high. As an example, the average cost of treating a single PI in Germany is estimated at €50.000. In the Netherlands, the annual amount of PI prevention and therapy (including adult and paediatric PIIs) adds up to an estimated €320 million, constituting 1,3% of the total annual healthcare costs. (Schlüer, Cignacco, Müller & Halfens 2009, 3244.)

Despite a growing number of studies on incidence and prevalence of paediatric and neonatal pressure injuries, the knowledge of particular risk factors is scarce (Manning, Gauvreau & Curley 2015, 343). This fact becomes strikingly obvious when looking at the existing PI assessment scales. Almost all of them are validated for adults and only a few have been recently adjusted to allow application to paediatric patients (Willock, Habiballah, Long, Palmer & Anthony 2016, 120) of which even fewer suit the neonatal population (Garcia-Molina & Balaguer-Lopez 2014, 1). This is an issue of great concern as the adult scales and even the adjusted paediatric scales do not consider the intrinsic characteristics of neonates (*ibid.*, 1).

Protecting skin integrity is a major part of nurses' work and they are obliged to use their clinical knowledge and experience to prevent skin and tissue injury (Willock & Maylor 2004, 62). Yet, Garcia-Molina and Balaguer-Lopez (2014, 1) state that the greatest risk factor for PIs is the disbelief of health professionals that they occur in hospitalized neonates. According to Schindler, Mikhailov, Cashin, Malin, Christensen & Winters (2013, 339) it is crucial for nurses to understand the physiologic indices of PI development and their interventions should be based on evidence-based information. Identification of true risk factors must be accomplishable for nurses in order to prevent neonates from unnecessary suffering but also to avoid unnecessary expenses by applying needless preventative measures (Willock & Maylor 2004, 56).

The aim of this literature review is to determine current risk factors for iatrogenic pressure injuries in neonates. The purpose is to raise awareness on the issue among nurses and point out the need for further research on neonate-specific risk factors. Further, up-to-date knowledge shall be provided for paediatric nurses and, help to reduce incidences of iatrogenic pressure injuries in neonatal care settings. Finally, the authors want to provide an impulse to

create an efficient assessment tool that helps nurses to diminish iatrogenic events.

2. Pressure Injuries

2.1 Pressure injury definition

The National Pressure Ulcer Advisory Panel (NPUAP) claims to be a national (USA) authoritative voice and their definition of PI stages is frequently referred to (e.g. Fischer, Bertelle, Hohlfeld, Forcada-Guex, Stadelmann-Diaw & Tolsa 2010, F448; Schindler et al. 2013; Visscher & Taylor 2014, 1). As of April 2016 (NPUAP 2016a) the stages have been re-defined and additional stages have been presented.

The NPUAP, among others (e.g. August, Edmonds, Brown, Murphy & Kandasamy 2014), acknowledged that a significant change in terminology was necessary. The term 'ulcer' does not apply for all PI stages, as the first stage and the deep tissue injury describe injured but intact skin that do not contain ulceration. Therefore, while the term 'pressure ulcer' is still commonly used, NPUAP advises to replace it by the term 'pressure injury'. (NPUAP 2016a.) The NPUAP defines a pressure injury as following:

"A pressure injury is localized damage to the skin and/or underlying soft tissue usually over a bony prominence or related to a medical or other device. The injury can present as intact skin or an open ulcer and may be painful. The injury occurs as a result of intense and/or prolonged pressure or pressure in combination with shear. The tolerance of soft tissue for pressure and shear may also be affected by microclimate, nutrition,

perfusion, co-morbidities and condition of the soft tissue." (NPUAP, 2016a.)

2.1 Pressure Injury Stages

PIs are divided into four stages. In addition, the NPUAP added a description of unstageable and deep pressure injuries. (NPUAP 2016a.)

Stage 1: non-blanchable erythema

The first stage of a pressure injury is characterized by non-blanchable redness of the skin (erythema). The epidermis is still intact, but when pressing the localized area, the erythema does not disappear within 30 minutes. There may also be changes in the skin's temperature or the consistency of tissue. In case of darker skin, there are different signs to be considered. The injured area can appear unrelenting blue, dark red, or purple. (NPUAP 2016b; August et al. 2014.)

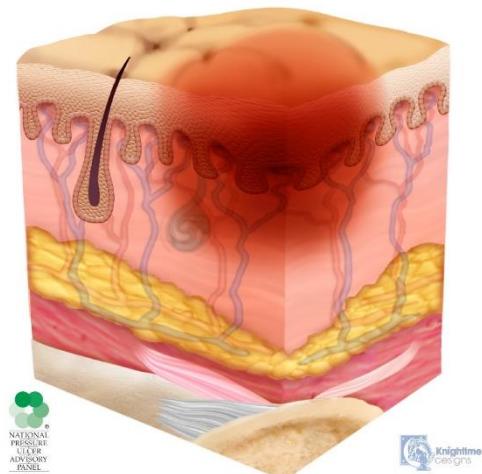


Figure 1. Stage 1 PI: non-blanchable erythema (NPUAP 2016c)

Stage 2: partial thickness skin loss

In stage 2, a partial-thickness loss of the skin occurs. This involves the epidermis, which makes the dermis being exposed, but does not fully penetrate the dermis. The color of the moist wound base is pink or red and it might present blistering. (NPUAP 2016b.)

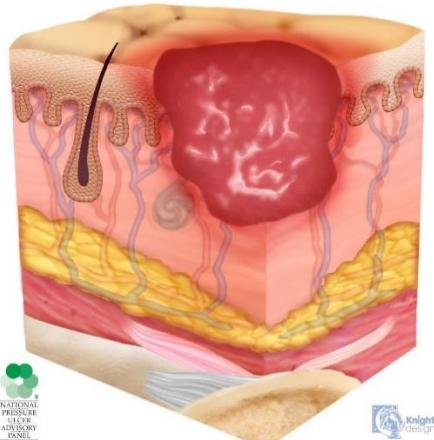


Figure 2. Stage 2 PI: partial thickness skin loss (NPUAP 2016c)

Stage 3: full thickness skin loss

In this stage there is full-thickness loss of skin. A shallow crater is formed and subcutaneous tissue is visible. The crater might be filled with eschar and the ulcer can contain necrotic and granulation tissue. Also rolled wound edges (epibole) are often present. The depth of the ulcer depends on the location of the ulcer. Areas that contain more adiposity are at risk of developing deep wounds, sometimes causing undermining and tunneling. (NPUAP 2016b.)

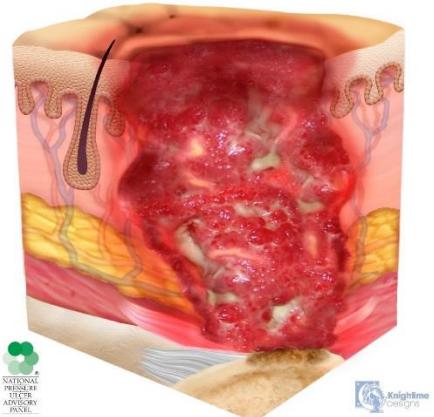


Figure 3. Stage 3 PI: full thickness skin loss (NPUAP 2016c)

Stage 4: full thickness tissue loss

This stage is characterized by full-thickness destruction and involves extensive tissue damage to fascia, muscle, tendon, ligament, cartilage or bone. An ulcer in this stage can also contain slough and/or eschar, and might be showing epibole, undermining and tunneling. (NPUAP 2016b.)

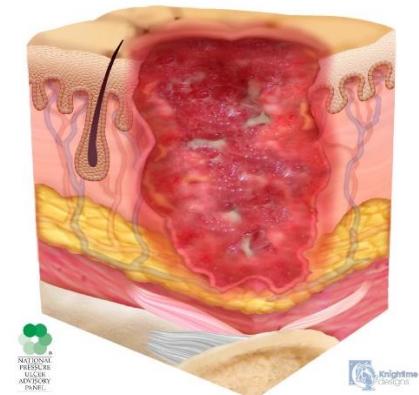


Figure 4. Stage 4 PI: full thickness tissue loss (NPUAP 2016c)

Unstageable Pressure injury

Some pressure injuries are difficult to classify as the wound is concealed by slough or eschar. The wound is likely to be a stage three or four injury when slough or eschar is removed. (NPUAPb 2016b.)



Figure 5. Unstageable PI – dark eschar (NPUAP 2016c)



Figure 6. Unstageable PI - slough and eschar (NPUAP 2016c)

Deep Tissue Pressure Injury

Due to intense and/or prolonged pressure and shear forces at the interface of the bone-muscle, a deep tissue injury might appear. The intact or damaged skin is presented with a non-blanchable deep red, maroon, purple discoloration. Epidermal separation might reveal a dark wound bed or a blood filled blister. Sometimes the wound resolves without tissue loss, but it may also evolve rapidly revealing the actual extent of tissue injury (NPUAP 2016b.)

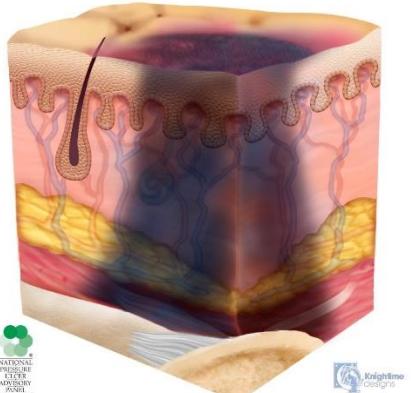


Figure 7. Deep tissue PI (NPUAP 2016c)

3. Pressure Injuries in Neonatal Care

3.1 Neonatal Development

Discussing the issue of pressure injury formation in newborns requires sufficient knowledge on their physiological and cognitive properties and impairments. There are certain factors that make newborns prone to suffer from skin injury, as there are for elderly, presenting them both as risk groups (e.g. August et al. 2014, 130, Levy, Kopplin & Gefen 2016; Razmus, Lewis & Wilson 2008, 36; Visscher & Narendran 2014a; Worsley, Smith, Schoonhoven & Bader 2016, 153). Especially, pre-term babies exhibit physiological underdevelopment increasing the risk even more (Fujii, Sugama, Okuwa, Sanada & Mizokami 2010, 323; Oranges, Dini & Romanelli 2015, 587; Parnham 2012, 25). Physiological and cognitive characteristics relevant for an elevated skin injury risk differ between preterm *vs.* full-term neonates (Table 1).

Table 1. Physiological and cognitive characteristics of preterm *vs.* full-term neonates (Holsti, Grunau & Shany . 2011; MacDonald & Seshia 2016)

Characteristic	Preterm	Full Term
tactile sensation	>15w GA (gestational age) sensitivity to touch; very low threshold -> tactile hypersensitivity (minimal handling intervention)	ability to compensate overstimulation; skin contact is comforting
pain	>20w GA nocireception fully functional but lack of inhibitory control mechanisms -> low pain threshold Assessment via: facial expressions (to a lesser extent), physiological items	pain habituation possible Assessment via: facial expressions, body movement, posture/tone, cry/vocal, behavioural state/sleep pattern,

	(HR, SpO ₂ , resp. rate, skin colour)	physiological items, consolability
Note: display of indicators less reliable as in full-terms		
<hr/>		
movement	less active; extended posture	brisk movement; flexed posture
<hr/>	<hr/>	<hr/>
muscle tone	weak	distinct
<hr/>	<hr/>	<hr/>
reflex response	weak or incomplete	distinct
<hr/>	<hr/>	<hr/>
sucking, swallowing, gag reflex	weak (nasogastric tube intervention)	distinct
<hr/>	<hr/>	<hr/>
respiratory ability	surfactant deficiency and immature lung anatomy; risk of RDS (ECMO, CPAP, O ₂ intervention)	lung maturity
<hr/>	<hr/>	<hr/>
thermoregulation	impaired; no fat stores, large body surface, poor microcirculation	functional
<hr/>	<hr/>	<hr/>
ear cartilage	≤28 w GA small amount of ear cartilage and/or a flattened pinna, ear is soft and flexible	well-curved pinna with firm cartilage
<hr/>	<hr/>	<hr/>
facial expression	few	manifold
<hr/>	<hr/>	<hr/>
interaction	poor	distinct non-verbal interaction
<hr/>	<hr/>	<hr/>
vasoconstriction	poor	peripherally functional
<hr/>	<hr/>	<hr/>
body surface area	very large; disproportional large head	large; disproportional large head
<hr/>	<hr/>	<hr/>
energy level	limited glycogen storage	normal glucose storage
<hr/>	<hr/>	<hr/>
vocal expression	whimpering, moaning	crying
<hr/>	<hr/>	<hr/>

functional small vessel density (FSVD)	very low -> tissue nutrition ↓ tissue perfusion↓	low
skin	see chapter 3.2	see chapter 3.2

It seems obvious that many of the above mentioned factors increase the risk of PI development in neonates. Especially, the impaired ability to express pain in preterm neonates poses great difficulty for nurses to identify and address pain caused by pressure (Pölkki, Korhonen, Laukkala, Saarela, Vehviläinen-Julkunen, & Pietilä, 2010, 49). However, the immaturity of the skin correlates with many of the listed characteristics and therefore seems to be a major factor regarding the vulnerability towards PI's in neonates (Oranges et al. 2015, 587).

3.2 Neonatal Infant Skin

The skin is a newborn's largest organ and has essential functions for survival (Pasek, Geyser, Sidoni, Harris, Warner, Spence, Trent, Lazzaro, Balach, Bakota & Weicheck 2008, 125). These include regulation and modulation of transepidermal water fluxes, thermoregulation, maintenance of electrolyte homeostasis, protection against pathogens, toxins, radiation and trauma as well as tactile sensation (Darmstadt & Dinulos 2000, 757).

Even though the skin composition is similar in adults and neonates with respect to layers and lipid composition, physiological changes occur after the transition from the aqueous, sterile intrauterine environment to the dry, non-sterile extrauterine environment (Afsar 2010, 856). It is necessary to understand the basic skin anatomy (see Fig. 8) and physiology in order to identify risks that are specific for the neonatal skin.

The epidermis represents the outermost layer of the human skin and is composed of the following four types of cells (with their respective protective functions): 1) keratinocytes (abrasions, heat, microbes, chemicals; producing water-repellent sealant); 2) melanocytes (UV-radiation); 3) Langerhans cells (immunosurveillance); 4) Merkel cells (touch sensation). The avascular epidermis is connected to the thicker vascular dermis, which consists of elastic fibers and has immense tensile strength. (Tortora & Derrickson 2011.)

The stratum corneum (SC) is the top layer of the epidermis, which is difficult to penetrate and thus constitutes an effective protection. Consisting of corneocytes (dead keratinocytes) that are connected by desmosomes and the interstitial space filled with lipid bilayers, it represents a barrier against environmental agents while allowing transepidermal water vapor. A normal adult SC consists of 25-30 layers. Appropriate SC hydration is a critical issue, since too much hydration can cause damages to the lipid bilayer structure, increased permeability, swelling, urticaria, irritation and inflammation. Dehydrated SC on the other hand poses the threat of dryness, itching, reduced flexibility and abnormal desquamation due to decreased enzymatic function. (Tortora & Derrickson 2011.) The enzyme activity strongly depends on an acidic pH-level of the epidermis (Visscher & Narendran 2014a, 139-140).

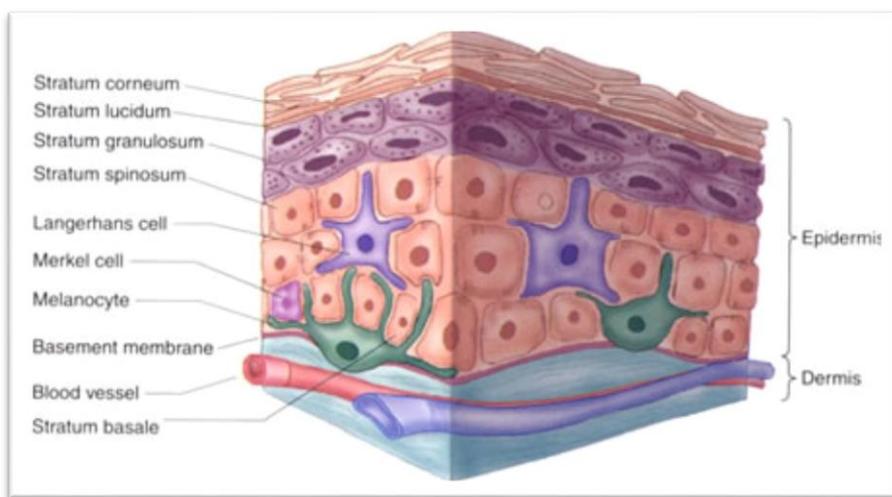


Figure 8. Skin layers (CT Esthetic 2013)

During fetal development the epidermal layers are fully keratinized by 34 weeks of gestation (Ness, Davis & Carey 2013, 15; Afsar 2010, 346), meaning the composition of the fetal skin is similar to adults with a notably lower number of each layer. The SC starts developing in the third trimester of pregnancy at the same time when the vernix caseosa is produced and supports the formation of SC despite the aqueous environment in utero. Vernix caseosa is a biofilm covering the fetus and is composed of water, lipids and detached corneocytes. It protects the fetal skin from the fluid environment in utero and acts as a lubricant during birth. (Afsar 2010, 346.) Research has demonstrated the positive effects of vernix caseosa on thermoregulation, skin hydration and infection protection after birth if left on the skin initially (Visscher & Narendran 2014b, 146).

The full term infant skin composition is fully developed at birth, yet its function is still developing and the barrier property impaired. SC hydration decreases right after birth due to low levels of the natural moisturizing factor, causing dry skin. It takes about two weeks for the SC to bind water sufficiently (Visscher & Narendran 2014a, 137). Another factor that needs postnatal adjustment is the neutral pH of the skin surface characteristic for neonates. Establishing the required skin acidity (~ 5.2 – 5.9) takes place progressively during the first three months after birth. (Visscher & Narendran 2014a, 137.) A decrease in skin pH enhances SC integrity and reduces the risk of mechanical trauma (Ludriksone, Bartels, Kanti, Blume-Peytavi & Kottner 2014, 593).

The SC is underdeveloped in the premature infant with only a few layers of corneocytes and mechanical and antimicrobial properties are poor varying with gestational age (Oranges et al. 2015, 588). The vernix caseosa is usually absent in very low birth-weight infants (VLBW), i.e. <28 weeks gestation and <1000 g (Singh & Archana 2008). Infants born between gestational weeks 23 and 38 are

more prone to suffer from transepidermal water loss (TEWL), hence dry skin, electrolyte imbalances, infection and skin damages (Visscher & Narendran 2014a, 138).

Their epidermis is lacking the detoxification properties and toxic substances can be absorbed without alteration to non-toxic derivates increasing the risk of sepsis (Oranges et al. 2015, 592). In addition, a premature child's dermis does not contain sufficient numbers of collagen and elastin fibers which is why the dermal-epidermal junction is weak posing a higher risk of damage due to disruptive forces, such as friction (Ness et al. 2013, 14). A high fluid content/tissue oedema can reduce the blood supply to the epidermis increasing thus the risk of necrotic injuries due to pressure (*ibid.*). In fact, studies have demonstrated that the neonatal incompetent epidermis might be a predisposing factor for the development of skin injury and sepsis. These factors are related to approximately 50% of neonatal deaths (Fluhr, Darlenski, Taieb, Hachem, Baudouin, Msika, De Belilovsky & Berardesca 2010, 483; Oza, Lawn, Hogan, Mathers & Cousens 2015, 20).

However, after being exposed to the dry extrauterine environment, SC development occurs as fast as in full-term infants and can further be manipulated by low humidity treatment in the incubator triggering cell proliferation (Denda, Sato, Tsuchiya, Elias & Feingold 1998). Also skin acidity decreases fast and significantly in preterm infants during the first ten postnatal days (Ludriksone et al. 2014).

3.3 Prevalence of Iatrogenic Pressure Ulcers in the Neonatal Population

Pressure injury prevalence studies often exclude paediatric patients (Schlüer et al. 2009, 3245). Even less studies are conducted specifically in neonatal patients (August 2013, 130; Visscher & Taylor 2014, 1). Many of the articles analyzed for this review present PI prevalences of observed patients (Fig. 9).

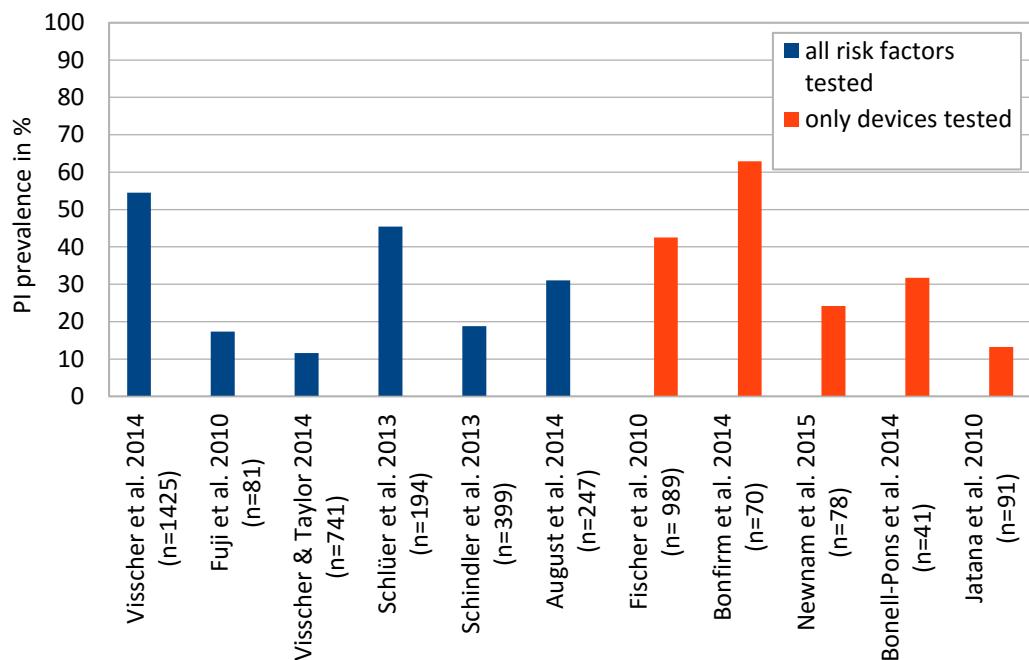


Figure 9. PI prevalence (proportional occurrence among all observed neonatal patients reported in the articles analyzed for this review. Data sets in blue show the prevalence in studies that covered all risk factors of PI development. Orange data sets represent those studies that observed exclusively device-related.

It can sometimes be difficult to interpret these figures, as the number of cases reported depends on the method of data collection, the reliability of reporting, and whether all the data collectors have been trained to recognize all grades of pressure ulcers (Willock et al. 2009, 14).

4. Risk Assessment Tools

There is a small amount of assessment tools used in order to assess the risk of pressure ulcers in pediatrics (Baharestani & Ratliff, 2007). Fewer tools seem to be suitable for neonatal patients and the ones existing have not been validated extensively (August et al. 2014; Stansby, Avital, Jones & Marsden 2014). This chapter provides a short overview of risk and skin assessment tools being used in neonatal care. Baharestani & Ratliff (2007, 210) refer to scholars, who criticize that the Updated Neonatal Skin Risk Assessment Scale (NSRAS), the Braden Q Scale (see appendix 9.2) and the Glamorgan scale (see appendix 9.3), are the only ones that have been tested for sensitivity and specificity. Willock et al. (2016, 124) consider these tools to be validated most widely and they recommend their implementation until other tools have been approved.

Braden Q

The Braden Q scale for paediatric patients (see App. 2) was developed in 1996 based on the Braden scale for adults. Like the Braden scale, it includes mobility, activity and sensory perception when assessing the intensity and duration of pressure. The Braden Q scale differs from the original Braden scale by an added seventh sub-item, i.e. tissue perfusion/oxygenation. (Noonan, Quigley & Curley 2011, 1-3.) The Braden Q is an assessment tool that has been validated in the assessment of risk for pressure ulcers in children from 3 weeks to 8 years of age (Tume, Siner, Scott & Lane 2014, 2). A more recent comparative study has been done on the validity of the Braden Q and the Glamorgan paediatric pressure ulcer risk assessment scales also for neonatal patients (Willock et al. 2016, 119-126). According to this study, both tools appear to be appropriate to predict the risks of pressure ulcers in neonatal patients (*ibid.*, 122-125).

Glamorgan Paediatric Pressure Ulcer Risk Assessment

The Glamorgan paediatric pressure ulcer risk assessment is based on the following risk factors: mobility, equipment, anaemia, pyrexia (fever), poor peripheral perfusion, inadequate nutrition, low serum albumin and (incontinence). According to Willock et al. (2016, 124-125) nurses mostly prefer the Glamorgan over the Braden Q scale because of practicality as it is designed for use in children.

Neonatal Skin Risk Assessment Scale (NSRAS)

Huffiness and Logsdon developed the internationally used NSRAS specifically for the neonatal patient, also based on the adult Braden Scale. The subscales are divided in six parts and include: general physical condition, mental status, mobility, activity, nutrition and moisture. A revised version of this tool appeared, as the incubator capabilities developed over the years. With the current NSRAS it is possible to measure the neonate's activity that is 'completely bed-bound in a humidified giraffe'. (Huffines 2013, 6.)

Neonatal Skin Condition Score (NSCS)

The NSCS is a skin assessment tool for newborns. The NSCS does not, in comparison to the aforementioned tools, analyze risk factors. It represents a method for reporting the newborn's skin condition in a concise and objective manner. The tool assesses the dryness, erythema and the breakdown/excoriation of the skin (Lund & Osborne 2004, 321 - 325).

Neonatal Infant Pressure Injury Risk and Assessment tool (NIPIRA)

August et al. (2014) developed this tool specifically for neonatal patients but it has been applied only to their study. The tool is not publicly available, but based on their study could be assumed that the following aspects will be assessed: limited mobility, reduced activity, decreased sensory perception, tissue tolerance/ altered tissue perfusion, nutritional status, skin temperature,

skin moisture and friction/shear forces (*ibid.*, 131). The NIPIRA will not be finalized until the completion of a multi-center/ prospective study that is currently in process. The team working on the tool concluded that there was not enough evidence to validate the final version (August et al. 2013).

Seton Infant Skin Risk Assessment (SISRA)

Another tool under development is the SISRA. A Delphi study technique was used to develop a skin breakdown risk assessment tool for infants from 23 weeks' gestation to 1 year of age. The developers strive to test and validate the tool prospectively for reliability, sensitivity, specificity, and predictive value. (Vance et al. 2015.)

5. Study Design

5.1 Aims, Purpose and Research Question

The aim of this literature review is to determine current risk factors for iatrogenic pressure injuries in neonates. The purpose is to raise awareness on the issue among nurses and point out the need for further research on neonate-specific risk factors. Further, up-to-date knowledge shall be provided for paediatric nurses and, help to reduce incidences of iatrogenic pressure injuries in neonatal care settings. Finally, the authors want to provide an impulse to create an efficient assessment tool that helps nurses to diminish iatrogenic events.

Research Question:

What are the current risk factors for iatrogenic pressure injury formation in neonatal care?

5.2 Literature Review

A literature review should give the reader up-to-date information on the set topic based on current literature (Cronin, Ryan & Coughlan 2008, 38). The aim of evidence-based nursing is to find, combine, analyze and summarize the best available research and clinical experience on a specific topic (Gray & Grove, 2016, 431). A literature review is a sufficient method in order to synthesize findings of clinical evidence (Gray, 2016, 62). It uses explicit, systematic methods (Moher, Shanseer, Clark, Ghersi, Liberati, Petticrew & Stewart 2015, 1) and is therefore acknowledged to be least biased and most rational (Thomas & Harden 2008). Following predesigned guidelines including transparent steps and clearly formulated research questions, a well-conducted literature review allows identifying and critically assessing available research in combination with drawing professional conclusions for the benefit of practical use (Moher et al. 2015, 1). Risk factors for neonatal PIs seem manifold and one study does not always investigate all of them. This fact, additional to the lack of awareness on the topic in general led to the decision to conduct a literature review. It is intended to gather knowledge and provide it comprehensibly.

5.3 Literature Search

For this thesis two independent reviewers conducted the search based on pre-defined eligibility criteria (see next paragraph) to minimize bias and ensure consistency of the methodological approach. A search protocol was established before browsing databases to reduce arbitrariness and enable readers to comprehend methods and drawn conclusions.

Study eligibility

Inclusion criteria:

1. Original articles published or submitted to peer reviewed scientific journals
2. articles in english, dutch and german
3. published in 2010-2016
4. free access articles for students of Jamk and the University of Jyväskylä
5. paediatric study population including specific risk factor data in neonates
6. article describes the source of occurrence (risk factor) of the pressure injuries.

Articles not meeting the inclusion criteria were automatically excluded.

Data Sources

The following 4 databases were used to find all relevant articles meeting our inclusion criteria: CINAHL, PubMed, Academic Search Elite and Google Scholar. The latter poses a problem with accountability, repeatability and verifiability yet has been shown to be a sufficiently enough tool to accompany the traditional databases (Bramer, Giustini, Kramer & Anderson 2013, 115). Due to its acceptable coverage and precision the reviewers chose to include it as a source. Based on the PRISMA Statement (Moher et al. 2015) a decision tree for inclusion of reviewed articles was produced (Fig. 10).

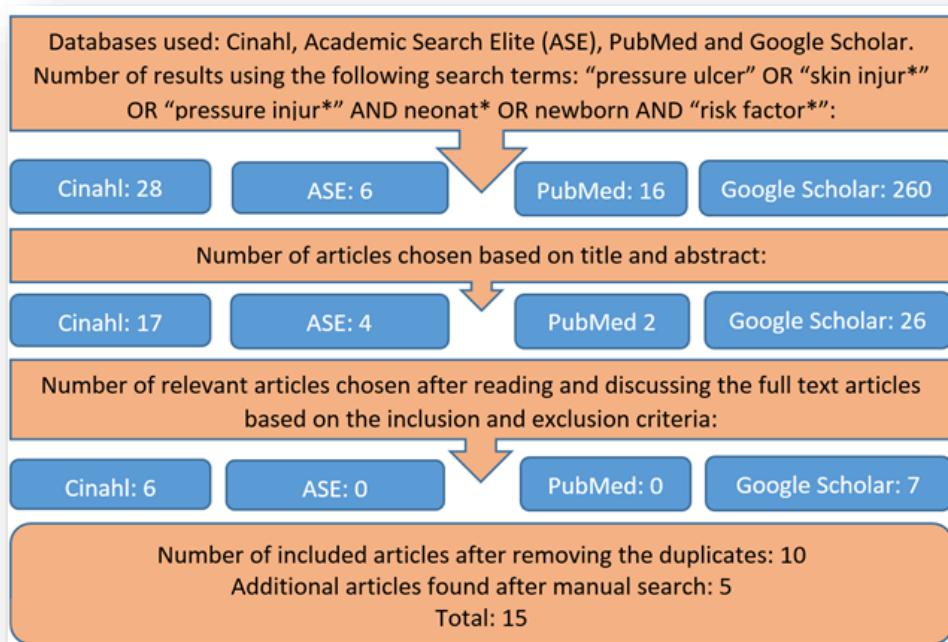


Figure 10. Decision tree for inclusion of articles to be reviewed

After selecting the articles to be reviewed, a manual search was conducted on the chosen articles' reference lists. The reference lists were browsed by both reviewers and the same inclusion criteria applied. Table 2 shows the complete list of articles used for the analysis.

Table 2. List of reviewed articles

Authors	Year	Country	Design	Title	Main findings
August et al.	2013	Australia	descriptive cohort study	<i>Pressure Injuries to the Skin in the Neonatal Unit: Fact or Fiction</i>	indwelling vascular catheters, nCPAP devices and oxygen saturation and temperature probes were identified as risk factors for PI
Bonell-Pons, Garcia-Molina, Balaguer-	2014	Spain	observational, analytical, longitudinal study with a	<i>Neonatal Facial Pressure Ulcers Related to Non-invasive</i>	pressure ulcers are associated with the use of diagnostic and therapeutic devices

Lopez, Montal & Rodriguez		retrospective design	<i>Ventilation: Incidence and Risk Factors</i>	like non-invasive ventilation devices in neonatal intensive care units
Bonfirm, Vasconcelos, Sousa, Silva & Leal	2014 Brazil	cohort study	<i>Nasal Septum Injury in Preterm Infants Using Nasal Prongs</i>	length of treatment was a determinant factor for occurrence and severity of PI due to nasal prongs.
Fischer, Bertelle, Hohlfeld, Forcada- Guex, Stadelmann- Diaw & Tolsa	2010 Switzerland	prospective observational study	<i>Nasal Trauma due to Continuous Positive Airway Pressure in Neonates</i>	high incidence in nasal trauma due to CPAP incidence and severity correlates with gestational age and birth weight greater risk for neonates <32 gestational age most of the PIs appeared during the first 6 days
Fujii, Sugama, Okuwa, Sanada & Mizokami	2010 Japan	multi prospective cohort study	<i>Incidence and Risk Factors of Pressure Ulcers in Seven Neonatal Intensive Care Units in Japan</i>	birthweight, skin texture, incubator humidity and temperature, support surface and endotracheal intubation usage identified as risk factors
Hogeling, Fardin, Frieden & Wargon	2012 Australia	case study	<i>Forehead Pressure Necrosis in Neonates Following Continuous</i>	permanent scarring due to CPAP fixation equipment

					<i>Positive Airway Pressure</i>
Jatana, Oplatek, Stein, Phillips, Kang & Elmaraghy	2010	USA	cross-sectional study	<i>Effects of Nasal Continuous Positive Airway Pressure and Cannula Use in the Neonatal Intensive Care Unit Setting</i>	nasal complications due to CPAP low Apgar scores might increase the risk
Newnam, McGrath, Salyer, Estes, Jallo & Bass	2015	USA	three group prospective randomized experimental study	<i>A Comparative Effectiveness Study of Continuous Positive Airway Pressure-related Skin Breakdown when Using Different Nasal Interfaces in the Extremely low Birth Weight Neonate</i>	significant predictors for PI: number of days on CPAP and current mean post menstrual age
Peterson, Adlard, Walti, Hayakawa, McClean & Feidner	2015	USA	quality improvement project (PDCA)	<i>Clinical Nurse Specialist Collaboration to Recognize, Prevent, and Treat Pediatric Pressure Ulcers</i>	successful reduction of skin breakdown by a matching risk assessment tool, routine skin assessment and a risk-related care plan
Scheans	2015	USA	case studies	<i>Neonatal Pressure Ulcer Prevention</i>	skin breakdown occurs due to anatomic, physiologic and developmental factors
Schindler et al.	2013	USA	prospective, quasi-	<i>Under Pressure: Preventing</i>	PI incidence dropped significantly after

			experimental study	<i>Pressure Ulcers in Critically ill Infants</i>	implementation of a pressure ulcer prevention care bundle
Schlüer et al.	2013	The Netherlands	multicenter, cross-sectional, descriptive study	<i>Pressure Ulcers in Hospitalized Neonates and Infants; Prevalence, Risk Factors, Preventive Measures</i>	ventilation support devices increased the risk for pressure injuries more than twofold
Vance et al.	2015	USA	delphi study	<i>A Delphi Study for the Development of an Infant Skin Breakdown Risk Assessment Tool</i>	survey among professionals on potential risk factors for skin breakdown medical devices, age/birthweight adhesives, activity, comorbidities, skin integrity and tolerance, moisture/chemicals and nutrition/hydration perceived as risk factors
Visscher, King, Nie, Schaffer, Taylor, Pruitt & Keswani	2013	USA	prospective study	<i>A Quality-Improvement Collaborative Project to Reduce Pressure Ulcers IN PICUs</i>	quality-improvement intervention reduced pressure injuries high risk for device-related injuries in neonates

Visscher & Taylor	2014	USA	prospective study	<i>Pressure Ulcers in the Hospitalized Neonate: Rates and Risk Factors</i>	medical devices e.g. CPAP, low gestational age, low birth weight and skin characteristics identified as risk factors
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5.4 Data Analysis

Qualitative content analysis is widely used in nursing science research and as an analysis method it represents a means of systematically and objectively finding, categorizing, summarizing and describing phenomena on a chosen topic regardless of the research method used or the strength of evidence (Elo, Kääriäinen, Kanste, Pölkki, Utriainen & Kyngäs 2014, 1). Its aim is a condensed, broad-based description of phenomena, with the purpose of providing knowledge and facts, pointing out the essence and focus, presenting new aspects and a practical guide to action (Gray & Groves, 2016). Content analysis can be conducted in an inductive manner by first excavating relevant data from original texts and consecutively formulating categories which can then be grouped in order to generalize. The deductive approach starts with the general, beforehand established concepts and seeks to find fitting data accordingly. (Holopainen, Hakulinen-Viitanen & Tossavainen 2008, 80.) Both inductive and deductive content analysis include three different stages of processing the data: preparation, organization and reporting of results (Elo et al. 2014, 1). For the current thesis the inductive approach was chosen to analyze the data. This 'bottom-up' approach allowed to gather detailed information and to gradually find patterns in the results of the reviewed articles regarding PI risk factors. By categorizing the diverse findings, meaningful conclusions could be drawn.

In the preparation phase the articles to be reviewed were read and reduced by marking text units suitable for analysis. The reviewers applied open coding in

this phase in order to predefine themes (see Elo et al. 2014, 2). Single words or combinations of a few words were used as analytical units. The aim was to create a conceptual system, a general map of evidence based on specific information (Elo & Kyngäs, 2008, 109). After finishing this process of data extraction, all analytical units were gathered in a list.

In the second stage, data were organized by finding similarities and differences, formulating subcategories and finally main, general categories, thus abstracting. The process included finding an analytical unit, clustering and categorizing (see Fig. 11). The final stage includes a description of the results/phenomena using again either a deductive or inductive approach. (Elo et al. 2014, 2.) A narrative synthesis method is used to review the collected data. This method can be described as a written presentation of the results extracted from the chosen articles. (Boland, Cherry & Dickson 2014, 92.)

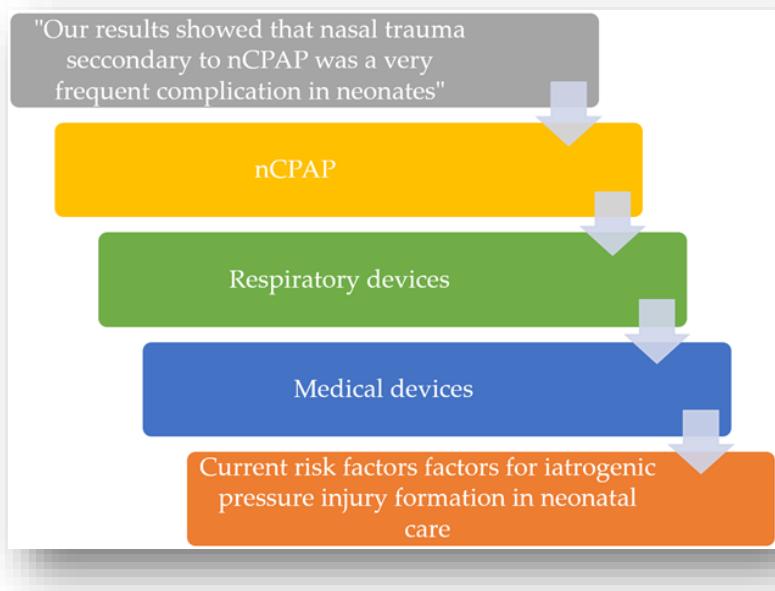


Figure 11. Example of clustering and categorizing

6. Results

The results are categorized in four main topics. Only the categories medical devices and medical condition of the neonate are sub-categorized (see Fig. 12).

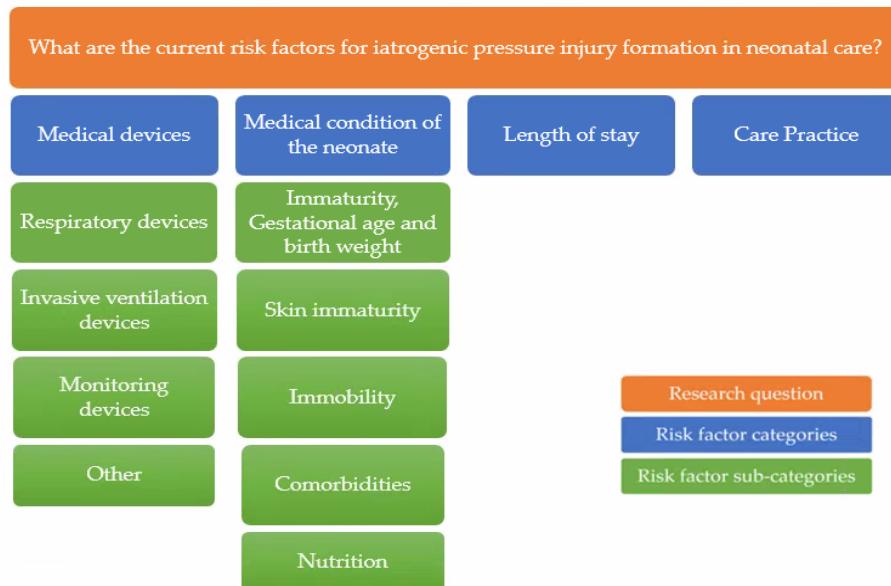


Figure 12. Top-down categorizing scheme

6.1 Risk Factors Related to Medical Devices

Pressure injuries in the neonatal population are frequently related to medical devices (Schlüer et al. 2013, 144; Visscher et al. 2013, 1954; Peterson et al. 2015, 277). Medical devices as the most common cause for PIs in neonates were described by August et al. (2014, 134) and Visscher and Taylor (2014, 2). Even after a successful quality-improvement, a collaborative project to reduce PIs in PICUs, PIs related to medical devices occurred continuously (Visscher et al. 2013, 1954). The intervention proved inefficient in facemask-associated PIs (*ibid.*, 1954). In Visscher and Taylor's (2014, 2) study, neonates with device related PIs seemed to develop a PI at a younger age than patients with

conventional PIs. They argue that the physiologic characteristics of the neonatal skin might be the reason for this. Additionally, the need to use medical devices is often a consequence of prematurity. (*ibid.*, 3.) The devices causing PIs in the neonatal population can be divided into the following four categories: respiratory devices, invasive ventilation devices, monitoring devices and other.

Respiratory Devices

In all reviewed studies, PIs due to respiratory devices were either found in a general setting (August et al. 2014; Fujii et al. 2010; Peterson et al. 2015; Scheans 2015; Schindler et al. 2013; Schlüer et al. 2013; Vance et al. 2015, 156; Visscher et al. 2013; Visscher & Taylor 2014) or the pivotal study object (Bonell-Pons et al. 2014; Bonfirm et al. 2014; Fischer et al. 2010; Hogeling et al. 2012; Jatana, 2010; Newnam et al. 2015) and have been demonstrated to constitute a pervasive, undeniable risk factor. In Schlüer et al.'s (2013, 146) dissertation study, ventilation support devices more than doubled the risk of PIs. Respiratory devices can be divided into two categories namely non-invasive respiratory devices and invasive ventilation devices.

Non-Invasive Respiratory Devices

According to Bonell-Pons et al. (2014, 33), non-invasive respiratory devices lead to an increase in the incidence of PIs, mainly affecting the nose. Both, NIPPV and nCPAP can be fitted to the nose with either a nasal prong or mask and both types have been reported to constitute a risk for PI development (Visscher & Taylor 2014, 4; Visscher et al. 2013, e1957; Peterson et al. 2015, 279; Newnam et al 2015, 41). More specifically at risk are the nasal septum, nasal cavities and bridge of the nose (Fischer et al. 2014; Fuji et al. 2010, 326; Jatana et al. 2010, 288-289; Bonfirm 2014; Peterson et al. 2015, 279; Visscher & Taylor 2014, 3). PIs due to nCPAP or DPAP more often advance to stage three ulcers on the NPUAP severity index compared to conventional PIs (Fischer et al. 2010, 449; Fuji et al. 2010, 326; Bonfirm 2014, 829; Visscher & Taylor 2014, 4). Visscher & Taylor

(2014, 4) assume this to be due to a combination of occlusion leading to ischemia and mechanical stress caused by the device. Two patients that have been developing stage three PIs are likely to require cosmetic surgery due to scarring (Fischer 2010, 450). Jatana et al. (2010, 288-289) found the PIs occurred within the anterior nasal cavity located at the tip of the nCPAP prong.

In Newnam et al.'s (2014) study, nasal prongs and masks were switched every 4-6 hours and were fixated by a hat with velcro moustaches. The outcome of Newnam et al.'s (2014, 5) study supports the rotation of the mask/prong interfaces as it reduces the frequency and severity of PIs. According to the study of Bonfim and her colleagues (2014, 832) the type of nasal prong used is not a determinant factor for developing nasal septum injury. Yet, they conclude that it is less likely to develop a nasal septum injury during the first day, when a new nasal prong is applied instead of a used one (*ibid.*, 831).

Some nCPAP fixation systems used, as reported in two case studies by Hogeling et al. (2012, 45-46), led to forehead pressure necrosis that resulted in permanent scarring. Peterson et al. (2015, 279) found that nurses were applying BiPAP masks too tight in order to prevent air leaks, what eventually resulted in PIs. A poor fit of a facemask can furthermore cause inhomogeneous pressure distribution resulting in PIs (Visscher et al. 2013, e1957).

The duration of nCPAP treatment was identified as a strong risk factor for PI development (Fischer et al. 2010, F450; Newnam et al. 2015, 5; Visscher & Taylor 2014, 3; Bonfirm et al. 2014, 832) even though Fischer et al. (2010, F450) report that the majority of nCPAP related PIs form in the first days of respiratory treatment. Upon nCPAP weaning, less severe ulcers started to heal immediately (*ibid.*, F450). Indisputable is the fact that the severity of PIs increases with prolonged treatment (Bonfirm et al. 2014, 831).

Invasive Ventilation Devices

Also invasive ventilation devices represent a significant risk factor (Bonell-Pons et al. 2014, 33; Fuji et al. 2010, 326; Peterson et al., 2015, 279; Schliuer et al. 2013, 146; Visscher et al. 2013, 1954; Visscher & Taylor 2014, 3-5;). Endotracheal tubes, tracheostomies and attached ties were identified as devices that have caused PIs (Fuji et al. 2010, 326; Visscher et al. 2013, 1954; Visscher & Taylor 2014, 3-5; Peterson et al., 2015, 279). Detailed information about PI location and severity is not provided, but Visscher et al. (2013, 1951) report complications with skin assessment underneath the device which is needed in order to prevent and care for PIs. In Fischer et al.'s study (2010, 449) nasal intubation did not reach significance as a risk factor for subsequent PI development under nCPAP treatment. Visscher and Taylor (2014, 5) found extracorporeal membrane oxygenation (ECMO) cannulas as a cause for PI's especially in term infants, which they argue is possibly due to the higher use of ECMO in term vs. preterm neonates. Additionally, ECMO cannulas might impede repositioning (Visscher & Taylor 2014, 3).

Monitoring devices

Pulse oximeters are commonly used in NICUs and are among the devices potentially causing PIs (Visscher & Taylor 2014, 3; Visscher et al. 2013, e1954). August et al. (2014, 134) showed that also temperature probes belong to this group of risk factors. Attached fairly tightly, both apply pressure on the skin, increasing the risk for PI development.

Other

Other medical devices/material causing PIs are cooling blankets, line hub, chest tube, nasojejunal tube, EEG leads, identification band, nasogastric tube and indwelling vascular catheters but with lesser impact than respiratory devices (August et al. 2014, Visscher & Taylor 2014, 5).

6.2 Medical Condition of the Neonate

Immaturity, Gestational Age and Birth Weight

A majority of the reviewed studies found a negative correlation between gestational age and the development of PI's, presenting it as a considerable risk factor (Bonell-Pons et al 2014, 33; Bonfirm et al. 2014, 832; Fischer et al. 2010, F450; Jatana et al. 2010, 289; Newnam et al. 2015, 39; Schlüer et al. 2013, 140; Vance et al. 2015, 155 and Visscher & Taylor 2014, 3). Additionally, three out of 15 research teams (Bonfirm et al. 2014, 832; Fischer et al. 2010, F450 and Visscher & Taylor 2014, 4) demonstrated that the severity of PI increased with lower gestational age, frequently resulting in stage three or four ulcers. However, Visscher & Taylor (2014, 3) showed, that the gestational age at the time of onset of PI development did not differ between preterm and full-term infants. This means that preterm infants are more prone to suffer from a PI, while its development span is much longer than in full-term infants (*ibid.*, 3).

A low birth weight was demonstrated as a risk factor for PI's by Fischer et al (2010, F450), Fujii et al. (2010, 326), Jatana et al. (2010, 289), Newnam et al. (2015, 38-39), Vance et al. (2015, 155) and Visscher & Taylor (2014, 3). Low birth weight and gestational age put neonates at increased risk for various reasons (Jatana et al. 2010, 289). A more vulnerable, smaller size of e.g. facial structures, especially the nasal cavity is mentioned as one, but also the higher likelihood of respiratory aid usage in preterm infants (*ibid.*, 289; Visscher & Taylor 2014, 3).

Skin Immaturity

Skin immaturity is widely mentioned to pose a risk for PI development (Fischer et al. 2010; Fujii et al. 2010; Jatana et al. 2010; Scheans 2015, 132 Vance et al. 2015, 155 and Visscher & Taylor 2014, 3).

Mechanical trauma due to excess moisture and oedema is frequently presented in the reviewed articles (Peterson et al. 2015; Schindler et al. 2013, 331; Vance et al. 2015, 155 and Visscher & Taylor 2014, 5). Skin occlusion via continuous contact to a surface or device and incontinence result in constant excess moisture levels in and around the skin, increasing the vulnerability for breakdown and infection (Schindler et al. 2013, 331; Vance et al. 2015, 155 and Visscher & Taylor 2014, 5). Friction levels are elevated by excess moisture, as well as by the underdeveloped junction of dermis and epidermis (Fuji et al. 2010, 327 and Visscher & Taylor 2014, 5) resulting in increased incidence and severity of pressure ulcers (Visscher & Taylor 2014, 4). Incubator humidity and temperature were associated with PI development in three of the 15 studies (Fuji et al. 2010, 326; Newnam et al. 2015, 40 and Schindler et al. 2013, 331) as they are playing a major role in preserving skin integrity.

Fuji et al. (2010, 327-328) identify “skin texture immaturity” as a major risk factor for neonatal PIs and recommend the use of the Dubowitz Neonate Maturity Assessment Scale (Dubowitz et al., 1980) for determining the maturity of the newborn’s skin. This would allow more accuracy in risk assessment e.g. in infants that are small for their gestational age. A great water/lipid ratio makes the already very thin layer of fat tissue soft and deformable (Levy et al. 2016, 2) and the skin maturation process is positively correlated with gestational age and weight (Oranges et al. 2015, 588). Conventional pressure injuries usually occur over bony prominences due to a lack of adipose tissue (Visscher et al. 2013, e1951) therefore making the latter two risk factors for PI development in premature and newborn infants. Visscher & Taylor (2014, 4) hypothesize that due to this insufficient fat tissue, device-related PI’s advance more often to stages III and IV.

Immobility

Neonatal immaturity implies a certain level of immobility depending on the gestational age and co-occurring diseases (Scheans 2015, 131; Schindler et al. 2013, 331 and Vance et al. 2015, 155). Lack of movement/inability to move oneself increases the duration of tissue interface pressure leading to aforementioned effects on skin integrity, thus representing another risk factor (Schindler et al. 2013, 331).

Comorbidities

Comorbidities in hospitalized neonates, in particular among preterm infants, are often marker for an elevated risk of iatrogenic PI's (August et al. 2014, 136; Peterson et al. 2015, 279; Scheans 2015, 131; Schindler et al. 2013, 339; Vance et al 2015, 156 and Visscher et al 2013, e1954). Respiratory and cardiovascular instability seem to be the most significant factors (Scheans 2015, 131), requiring support devices and/or vasopressive medication, while often leading to impaired tissue perfusion (August et al. 2014, 131; Peterson et al. 2015, 279 and Scheans 2015, 127). Hemodynamic issues (Peterson et al. 2015, 279), congenital diaphragmatic hernia (Visscher & Taylor 2014, 5), previous injuries (August et al. 2014, 136) and "presence of a heavy disease burden with secondary skin failure" (Schindler et al. 2013, 339) were reported to increase the likelihood of developing PI's. Visscher et al. (2013, e1954) mention craniofacial anomalies (e.g. micrognathia) as a comorbidity affecting PI development through interference with the face mask fit.

Nutrition

Nutrition is an important factor for skin integrity and malnourishment is acknowledged to represent a risk factor for PI development (Peterson et al. 2015, 279; Scheans 2015, 129; Schindler et al. 2013, 331 and Vance et al. 2015, 155). Poor nutrition causes low levels of serum albumin, calories, minerals and hemoglobin leading to reduced skin tolerance and impaired wound healing

(Scheans 2015, 129, 132 and Schindler et al. 2013, 331). Providing appropriate amounts of nutrients to preterm infants and ill/weak neonates is crucial and often requires total parenteral nutrition (TPN) (Scheans 2015, 132 and Schindler et al. 2013, 331) presenting these two groups of neonatal patients at high risk for malnourishment and thus PI development.

6.3 Length of Stay

Many of the studies found that the risk for PI in neonates increases with prolonged hospitalization (Bonell-Pons 2014, 33; Bonfirm et al. 2014, 832; Fischer et al. 2010, F450; Schlüer et al. 2013, 147; Schindler et al. 2013, 339; Visscher et al. 2013, e1957 and Visscher & Taylor 2014, 5). Even though Visscher & Taylor (2014, 5) question the value of days of hospitalization as a predictor for PI development, it is listed in the mentioned articles as a significant risk factor. Bonfirm et al. (2014, 832) point out that not only the incidence increases with prolonged treatment but also the severity of injury.

6.4 Care Practice

The difficulties in correctly assessing the risk factors for paediatric PI's and the need for improved assessment tools specifically for the vulnerable neonatal population were mentioned in many reviewed articles (August et al. 2014; Bonfirm et al. 2014; Fuji et al. 2010; Newnam et al. 2013; Peterson et al. 2015; Schindler et al. 2013; Vance et al. 2015; Visscher et a. 2013; Visscher & Taylor 2014). Some go further and identify the healthcare staff's lack of expertise and compliance with skin care practices as a risk factor itself (Peterson et al. 2015, 277 and Vance et al. 2015, 157). Peterson et al (2015, 277) state that nurses might

neglect the fact, that paediatric PI's are a considerable problem or lack the knowledge of properly assessing and identifying PI's in infants.

In Vance et al.'s (2015, 157) Delphi Study, interviewed nurses themselves admitted that lack of knowledge and/or compliance with evidence-based care among healthcare professionals puts the neonatal population at risk for iatrogenic events. Peterson et al. (2015, 280) report the occurrence of a hospital-acquired pressure ulcer (HAPU) after incorrect and inadequate use of a positioning device as a pressure reduction surface. They also identified, that nurses frequently attach devices too tightly, not being aware of the increased pressure risk (*ibid.*, 279).

Bonfirm et al. (2014, 831) refer to a study that identified decreased surveillance by nurses due to staff reduction at night or work overload during the day as a risk factor for nasal prong-related PI's. Accordance exists on the fact that the number of patient repositioning demonstrates a risk factor (Fuji et al. 2010, 326 and Vance et al. 2015, 155). Frequent changes of position are necessary to prevent elongated times of skin occlusion and to maintain circulation, yet might prove difficult in patients being intolerant of repositioning, e.g. due to their requirement of mechanical ventilation (Peterson et al. 2015, 279; Vance et al. 2015, 155). Only Peterson et al. (2015, 278) report a 'lack of appropriate (medical) products and (human) resources' in order to minimize the risk for PI development.

7. Discussion

7.1 Ethical Considerations

The Finnish Advisory Board on Research Integrity is an expert body that is appointed by the Finnish Ministry of Education, Science and Culture (Academy of Finland, 2014). The board has drawn up guidelines for researchers to conduct good scientific practice and also created procedures for handling misconduct and fraud in science. In order to conduct a research in a responsible manner, the authors followed the guidelines made by the Finnish Advisory Board on Research Integrity as advised by the Academy of Finland (2014).

There seems to be mutual recognition and acknowledgement between the research groups of the reviewed literature, which adds to the quality of the results. No evidence of dispute over contrary results could be found, but rather synthesis. A major benefit of most reviewed studies was the collaborative character of the approach by involving neonatal nurses on the wards in their data sampling. However, Fujii et al (2010, 327) raise concern over a possibly altered attitude the nurses might adopt just by the fact that a research team is present. Considering that evaluating a central nursing task, such as skin care, represents a delicate affair in terms of collaboration between staff and researchers, Fujii et al.'s (2010, 327) argument is legitimate. The main results of this review however, did not relate to the attitude or assessment skills of nurses but on risk factors that could be measured and documented well by the help of nurses.

7.2 Reliability, Validity and limitations

The limited amount of research on iatrogenic pressure injuries in the neonatal population and the lack of Finnish studies make it difficult to generalize the results of this review for other institutions, especially Finnish neonatal wards. Differences in type and rate of medical device use, education quality, hospital policy and resources between institutions can have a huge impact on the outcome. Nonetheless, this review provides indications of possible risk factors that should be investigated in order to reduce and preferably prevent suffering from these unfortunate events.

The reviewed articles were all published in high-quality, peer-reviewed scientific journals, yet the access was limited and a few original articles could not be included. The decision to choose the time frame of six years originates from already existing older reviews on the topic and recent findings that demonstrate the need to include a new perspective. Literature reviews were excluded, as they either provided information from the recent articles that are included in this review, or include articles that are done before 2010. Older research results might contradict results with the latest evidence based knowledge available. During the review process the authors selected and analyzed the original articles independently to avoid a bias in the results. The consensus concerning the selection of studies was 93% underlining the high reliability of this study.

7.3 Discussion of the Results

The aim of this literature review is to determine current risk factors for iatrogenic pressure injuries in neonates. Respiratory devices seem to be the

most common risk factor by far for neonates and even more so for preterm infants (Visscher & Taylor 2014, 1). A more thorough investigation of the topic seems therefore important and possibly shifting the focus in this direction. Especially, since new technologies enhance the survival of premature babies at a progressive rate (Sardesai, Kornacka, Walas & Ramanathan 2011, 197). Nowadays, neonates survive at a lower gestational age, but not without using an often immense amount of medical support (Marlow, 2015). Also neonates in poor medical condition survive better with the support of medical devices (*ibid.*). Scientific evidence in neonatal respiratory care promotes an early transition from mechanical ventilation to CPAP or NCPAP respectively to avoid the risks of invasive ventilation such as pneumonia and sepsis (Kirpalani, Millar, Lemyre Yoder, Chiu & Roberts 2013, 611; Lista, Castoldi, Fontana, Frongia, Mirjana, Tansini, L. & Pivetti 2013, 111).

Nurses play a crucial role in the success of this respiratory approach by acting together with doctors to achieve functional breathing (Lista et al. 2013, 112). These respiratory devices, as is shown in this review, demonstrate the problem that comes along with the blessing of advanced technological possibilities in the context of neonatal PIs. By using their professional experience in choosing the best-fitted devices and interfaces, nurses are obliged to continuously assess and prevent e.g. nasal trauma (Lista et al. 2013, 113). The positive aspect regarding the problem with medical devices is, that further research and evidence-based nursing education is capable of diminishing the risk of neonatal PIs. The nurses' awareness of risks and knowledge on preventative means will be the decisive factor if device-related PIs will continue to pose a distinct threat to the neonatal population (Lista et al. 2013, 113).

During the review process, the authors of this thesis often discussed about what is the actual risk factor for the specific PI in question. The poor medical condition of a neonate is a risk factor on its own. This leads automatically to

prolonged duration of treatment and hospital stay, both of which are considered risk factors on their own and imply the risk of longer exposure to medical devices. Without a doubt, medical devices are often the causative factor of PIs and even more so, do they seem to be the most common factor (Visscher & Taylor 2014, 1). Yet, the categorized results as shown in this review cannot be adapted as arbitrary. It is difficult to define true versus associated risk factors because of the interrelated causes of vulnerability (Vance et al. 2015, 156). For example, a neonate of low gestational age is likely to have a low birth weight, is possibly in poor physical condition and probably needs respiratory aid of some kind. It is difficult to state which of these led to the development of the pressure injury in question. Hence, the occurrence of PIs is a multifactorial process and should be approached accordingly (Garcia-Molina & Balaguer-Lopez 2014, 2). This review brought forward that a single risk factor is often not the only explanation for the development of a specific PI. In some cases, the causative factor could not be identified at all (August et al., 134).

Risk assessment tools are important as a platform for future investigation of PI management. Medical devices should be researched for future risk management and strategies to prevent PIs. (August 2013, 136.) Most risk assessment tools (see 2.4) are based on risk factors mainly from the infant's condition point of view. Interestingly, only the Glamorgan paediatric pressure ulcer risk assessment includes equipment as a risk factor despite the high causation of device-related PIs. The authors strongly suggest including medical devices as a crucial factor in a risk assessment tool despite the interrelation with other risk factors.

PIs can develop quickly, often within days (Fuji 2010, 326; Fischer et al. 2011, F450) and therefore neonates need to be observed intensively in order to prevent the development of PIs. Nurses should take responsibility for the observation of PIs as they are the most constant factor during the neonates stay

in the hospital. In order to observe efficiently, risk assessment scales are essential for nurses and they should be educated in using these tools (Garcia-Molina & Balaguer-Lopez 2014, 2). Also knowledge of the physiologic indices of PI development and interventions belongs to the basic skills a nurse working with neonates should have (Schindler et al. 2013, 339).

7.4 Conclusion and Recommendations for Further Studies

To conclude, the results of this review clearly show that a need for further research on risk factors underlying neonatal PIs exists. Because these factors seem naturally inter-related it is important to investigate them thoroughly and create assessment tools that are more specific and do not leave significant risks uncovered. A nurse might be able to rely on her professional experience in order to assess, prevent or treat neonatal PIs, yet it is recognized that there is a coercible need for raising awareness on PI existence and continuous evidence-based education of nursing staff. The authors of this review are not aware of any PI prevalence studies in Finnish neonatal wards but suggest conducting them regularly. When discussing the topic during the preparation of this review it became clear that the sheer existence of neonatal PIs is commonly not recognized among Finnish nurses. Hence, a Finnish prevalence study could confirm the results of this review in terms of increased need of awareness or provoke further research on why the Finnish neonatal PI prevention system might be so efficient. Another literature review that would demonstrate and evaluate the current care practices is recommendable.

8. References

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9. Appendices

App. 1 Abbreviation list

CPAP	continuous positive airway pressure
ECMO	extracorporeal membrane oxygenation
ELBW	extremely low weight
HAPU	hospital-acquired pressure ulcer
LBW	low birth weight
MDR	medical device-related
nCPAP	nasal continuous positive airway pressure
NICU	neonatal intensive care unit
NIPIRA	Neonatal Infant Pressure Injury Risk and Assessment Tool
NIPPV	nasal intermittent positive pressure ventilation
NMF	natural moisturizing factor
NSCS	Neonatal Skin Condition Score
NSRAS	Neonatal Skin Risk Assessment Scale
PI	pressure injury
PICU	paediatric intensive care unit
PU	pressure ulcer
SC	stratum corneum
SGA	small for gestational age
TPN	total parenteral nutrition
VLBW	very low birth weight

App. 2 Braden Q Scale

BRADEN Q SCALE: A risk assessment to be completed on admission and each 24 hours for patients with decreased level of mobility in relation to developmental age. Evidence of pressure ulcers will be defined using the classification system stage 1 to 4.

Intensity and Duration of Pressure		Score	
Mobility – Ability to change & control body position	1. Completely Immobile Does not make even slight changes in body or extremity position without assistance	2. Very Limited Makes occasional slight changes in body or extremity position but unable to completely turn self independently	3. Slightly Limited Makes frequent though slight changes in body or extremity position independently
Activity – The degree of physical activity	1. Bedfast Confined to bed	2. Chair Fast Ability to walk severely limited or non-existent. Cannot bear own weight &/or must be assisted into chair	3. Walks Occasionally Walks occasionally during day but for very short distances with or without assistance. Spends majority of each shift in bed or chair
Sensory Perception – The ability to respond in a developmentally appropriate way to pressure related discomfort	1. Completely Limited Unresponsive to painful stimuli due to diminished level of consciousness or sedation OR limited ability to feel pain over most of body surface	2. Very Limited Responds only to painful stimuli. Cannot communicate discomfort except by moaning or restlessness OR has sensory impairment which limits the ability to feel pain or discomfort over half of body	3. Slightly Limited Responds to verbal commands but cannot always communicate discomfort or need to be turned OR has sensory impairment which limits the ability to feel pain or discomfort in 1 or 2 extremities
Tolerance of the Skin and Supporting Structure		Score	
Moisture – Degree to which skin is exposed to moisture	1. Constantly Moist Skin is kept moist almost constantly by perspiration, urine, drainage, etc. Dampness is detected every time patient is moved or turned	2. Very Moist Skin is often, but not always moist. Linen must be changed at least every 8 hours	3. Occasionally Moist Skin is occasionally moist, requiring linen change every 12 hours
Friction – Shear	1. Significant Problem Spasticity, contracture, itching or agitation leads to almost constant thrashing and friction	2. Problem Requires moderate to maximum assistance in moving. Complete lifting without sliding against sheets is impossible. Frequently slides down in bed or chair, requiring frequent repositioning with maximum assistance.	3. Potential Problem Moves feebly or requires minimum assistance. During a move skin probably slides to some extent against sheets, chair, restraints, or other devices. Maintains relative good position in chair or bed most of the time but occasionally slides down.
Nutrition	1. Very Poor NBM &/or maintained on clear fluids, or IV's for more than 5 days OR albumin < 25mg/l	2. Inadequate Is on liquid diet or tube feedings/TPN which provide inadequate calories and minerals for age OR albumin < 30mg/l	3. Adequate Is on tube feedings or TPN which provide adequate calories and minerals for age
Tissue Perfusion and Oxygenation	1. Extremely Compromised Hypotensive (MAP < 50mmHg; < 40mmHg newborn) OR the patient does not physiologically tolerate position changes	2. Compromised Normotensive; Oxygen saturation may be < 95% OR haemoglobin may be < 100mg/l OR capillary refill may be > 2 seconds; Serum pH is < 7.40	3. Adequate Normotensive; Oxygen saturation >95%, normal haemoglobin, & capillary refill < 2 seconds; Serum pH is normal
Patient 'At Risk' / Mild Risk		'Moderate Risk'	'High Risk'
16 - 23	13 - 15	10 - 12	9 or below
'Very High Risk'		Score	

App. 3 Adapted Glamorgan Pressure Ulcer Risk Assessment Scale

NATVNS SCOTLAND		Adapted Glamorgan Pressure Ulcer Risk Assessment Scale		Suitable for use from Birth-18yrs		Admission Date..... Time..... Consultant/GP		Surname CHI No Forenames Sex Location..... QSH		WRITE, IMPRINT OR ATTACH LABEL	
N.B. This tool should be used to support not replace your clinical judgement as to whether the child is at risk of pressure ulcer development.											
Risk Factor (If data such as serum albumin or haemoglobin is not available, write NK – not known and score 0)	Score	Date and time of assessments (reassess at least daily and every time condition changes)									
Child cannot be moved without great difficulty or deterioration in condition / under general anaesthetic >2 hours	20										
Unable to change his/her position without assistance /cannot control body movement	15										
Some mobility, but reduced for age	10										
Normal mobility for age	0										
Equipment / objects / hard surface pressing or rubbing on skin	15										
Significant anaemia (Hb <9g/dl)	1										
Persistent pyrexia (temperature > 38.0°C for more than 4 hours)	1										
Poor peripheral perfusion (cold extremities/ capillary refill > 2 seconds / cool mottled skin)	1										
Inadequate nutrition/PYMS score >2 (discuss with dietitian if in doubt)	2										
Low serum albumin (< 35g/l)	1										
Incontinence (inappropriate for age)	1										
Total score											
Action Taken											
(Yes or no – Ensure plan of care is implemented / reviewed for all identified areas of concern											
Signature											