Heel pressure ulcer prevention: a 5-year initiative using low-friction bootees in a hospital setting

In the period 2011 to 2015, St Helens and Knowsley Teaching Hospitals NHS Trust evaluated low-friction bootees (LFB) integrated into the care path for patients at-risk of heel pressure ulceration (hPU) in an initiative to reduce hospital acquired hPU related to friction and shear. In 2012, LFB were introduced and hPU reduced by 32% from 50 to 34 compared with 2011. In 2013, mandatory education and training was introduced. A further reduction to 11 hPU from 34 was recorded. In 2014 a new risk assessment tool was introduced. Thereafter the incidence of friction/shear associated hPU, identified by the depth of tissue injury, stabilised. Over the initiative, the overall reduction in all PU was 67% and for hPU, 84%. No grade 3 or 4 hPU were reported. The incidence of all PU reported was, and remains, below the national average. The five-year initiative substantially impacted on achieving zero harm targets, and led to estimated savings calculated from the reduced cost of managing hPU and the cost of acquisition and laundering of LFB versus 2011 of £53,371 in 2012 and £196,116 in 2013.

DEBBIE GLEESON

Lead Nurse Tissue Viability, Whiston Hospital, Prescot, Merseyside, UK

Heel pressure ulcer prevention: a 5-year initiative using low-friction bootees in a hospital setting

KEY WORDS
- Friction/Shear
- Harms
- Heel
- Pressure ulcers

In the period 2011 to 2015, St Helens and Knowsley Teaching Hospitals NHS Trust evaluated low-friction bootees (LFB) integrated into the care path for patients at-risk of heel pressure ulceration (hPU) in an initiative to reduce hospital acquired hPU related to friction and shear. In 2012, LFB were introduced and hPU reduced by 32% from 50 to 34 compared with 2011. In 2013, mandatory education and training was introduced. A further reduction to 11 hPU from 34 was recorded. In 2014 a new risk assessment tool was introduced. Thereafter the incidence of friction/shear associated hPU, identified by the depth of tissue injury, stabilised. Over the initiative, the overall reduction in all PU was 67% and for hPU, 84%. No grade 3 or 4 hPU were reported. The incidence of all PU reported was, and remains, below the national average. The five-year initiative substantially impacted on achieving zero harm targets, and led to estimated savings calculated from the reduced cost of managing hPU and the cost of acquisition and laundering of LFB versus 2011 of £53,371 in 2012 and £196,116 in 2013.

DEBBIE GLEESON
Lead Nurse Tissue Viability, Whiston Hospital, Prescot, Merseyside, UK

Pressure, particularly over bony prominences such as the ischium, trochanter, elbows, heels and other anatomic sites, leading directly to tissue damage and restricting blood flow creating areas of cell death and ischaemia, has been widely recognised as a risk factor for pressure ulcers (PU) (Grey et al, 2006; Gefen et al, 2008; National Institute for Health and Care Excellence [NICE], 2014). The National Pressure Ulcer Advisory Panel (NPUAP), European Pressure Ulcer Advisory Panel (EPUAP) and Pan Pacific Pressure Injury Alliance (PPPIA) (2014) and other expert PU guideline developers further recognise friction that causes shear as a critical risk factor. Friction, caused by the interaction of a surface material such as a bed sheet with skin, which may also be affected by moisture, leads to tangential forces in the tissue when the surface of the skin is prevented from sliding as a patient moves on the surface. The resulting shear, where two layers of skin move excessively in relation to each other, leads to deformation of the skin and underlying tissues that may damage tissue directly (Reger et al, 2010) or cause injury to superficial skin structures when a patient moves on a bed surface (Dealey et al, 2015). In an at-risk patient the outcome may be tissue injury. Friction and shear are predictive for the development of PU in adult critical care patients (Cox, 2011) and friction is a significant risk factor in critically ill patients (de Laat et al, 2006). Along with moisture, pressure and friction/shear account for most tissue damage in vulnerable sites.

Heels are at risk because of the weight of the foot, the shape of the calcaneus, lack of padding and relatively poor blood supply (Langemo, 2014). The incidence of hospital-acquired hPU may be as high as 30% of patients (Bååth et al, 2016), demonstrating the need for interventions to minimise the risk of skin breakdown caused by pressure and other factors including friction and shear.

Many patients are susceptible to hPU and in many cases this may be related to friction and shear. Susceptible patients include those with reduced lower limb mobility as a result of other conditions (e.g. fractured hips, joint replacement surgery, spinal cord injury, Guillian Barré Syndrome or stroke); those with diabetic neuropathy; those with leg spasms; patients who frequently reposition by pushing their heels on a mattress (Fletcher, 2015).

Other risk factors include a previous history of hPU; dementia; agitation; lower extremity oedema (Black, 2004) and profiling beds (Fletcher, 2015).

Pressure is addressed by many products that are designed to redistribute pressure, including passive foam mattresses, cushions and wedge products, and advanced active mattresses. Moisture is managed by good practice and skin care with barrier products. Over the past 20 years with the availability of offloading products and pressure redistributing mattresses and surfaces, and associated clinical practice to reduce pressure, the incidence of PU in the UK has reduced steadily. Safety Thermometer reporting in June 2013 highlighted a 45% reduction in all grade 2 to 4 PU versus prior year and the incidence of PU was reducing month on month (McIntyre 2013). This has been sustained for the past three years as shown by published Safety Thermometer figures for new pressure ulcer harms, from 2012 to 2016 (the national mean is 1% and at St Helens and Knowsley it is 0.17%). Reduced friction has been addressed by wound dressings (Bots and Apotheker, 2004) which laboratory testing shows provide varying coefficients of friction (CoF), the lowest being over 0.3 (Call et al, 2015).

Garments manufactured using low friction fabrics offer another potential solution for injury related to friction and shear. Low friction bootees (LFB) and undergarments (APA Parafricta, Bedford, UK) are intended to reduce the risk of the development and progression of skin damage caused by friction and the resulting shear in people who have, or are at risk of developing PU, and in people with frail skin or those who have medical conditions in which skin frailty is a primary factor. In particular, LFB provide low friction protection for the heel and ankle.

The population covered by St Helens and Knowsley NHS Trust is likely to be at higher risk of PU formation because of the level of general health and the presence of severe chronic health-related conditions. Whiston Hospital has 887 beds, providing a full range of acute services across two sites to a population of 350,000 people with a higher than the national average incidence of heart disease, lung cancer and chronic lung disease (CQC, 2016).

In 2012, the Trust initiated an evaluation of LFB in the prevention of hPU since, prior to the evaluation, the Trust were aware that the number of hPU was increasing year-on-year despite the use of interventions including film dressings to protect heels and pressure relieving mattresses. The recent commercial availability of the LFB made it possible to evaluate the potential of low friction fabric products to address this problem. The Trust's primary focus was to reduce the overall incidence of pressure ulcers, and address the challenge of hPU.

IMPLEMENTATION

With the availability of the new technology, the Trust opted to evaluate LFB for hPU. The first 2 years' data from this report were published (Gleeson, 2015). The current paper extends the initiative for a further two years, over which time an enhanced care standard was introduced, and reports the overall outcome of the initiative to the end of 2015.

In 2011, the year prior to implementation of the LFB incidence data for PU grades 1 to 4 for all anatomic sites (125 PU) with the subset of hPU identified separately (50 PU) provided the baseline for comparison of outcomes through the initiative. *Table 1* provides details. LFB were introduced for all at-risk patients in 2012. Education and training on the prevention and management of PU, including hPU for 1800 staff, delivered by the lead Tissue Viability Nurse in one-hour sessions over approximately one year, were mandated in 2013. The risk assessment tool, developed from the Maelor Score, a widely used risk assessment method (Vowden, 2012; Moore et al, 2015), with additional risk categories based on the work of Black (2004), assesses 11 patient-specific risks to identify patients at risk of developing hPU. The tool retains the risk assessment provided by the Maelor Score which is used for all patients, and focuses further on hPU through an additional assessment for patients at risk of hPU formation. Additional risks assessed are history of heel ulcer, diabetes, stroke, paralysis, hip fracture, dementia, peripheral vascular disease, leg spasms, agitation, leg oedema and sliding. Any patient with one or more of those risks must be allocated a LFB and the heels regularly assessed. While the full tool has not been formally validated, it is based on an established tool (Maelor Score: Vowden, 2012; Moore et al, 2015) augmented by published risk factors for hPU formation (Black 2004).

Declaration

APA Parafricta provided assistance in preparation of the manuscript. LFB were not provided free of charge but were purchased by the Trust. Figures for the number of LFB purchased during the initiative were provided by sales records kept by APA Parafricta.

LFB were issued from the hospital equipment pool according to the requirements of each ward after patients had been assessed for risk. The standard of care for patients identified as at risk of development an hPU before the start of the initiative included the following as recommended by NICE: use of an air offloading bootee, protective film dressings, two-hourly rounding and pressure reducing/relieving. Once the evaluation commenced, LFB were introduced alongside current practice. The Trust's risk assessment tool was introduced in mid-2014.

LFB are reusable. Once the patient was discharged, or if LFB needed changing, they were decontaminated in the standard hospital laundering process and returned to stock before re-allocation to at-risk patients. The indications for changing LFB were soiling or changes in foot size. Records for frequency of change were not available.

The incidence of hospital-acquired PU was monitored monthly according to standard practice in the Trust and annual outcomes were assessed according to the needs of the Trust. Incidence data for all PU and the subset of avoidable hPU for each year (as per objective) were compared to the baseline incidence in 2011 as was. For this evaluation, the definition of a pressure-related injury (without friction and shear) is an injury to subcutaneous tissues under intact skin (deep tissue injury/grade 1 pressure ulcer) which evolves over an extended period of time, and friction and shear-related injury is superficial and/or blistered healing within days (Reger et al, 2010). In order to determine the cause of any PU that developed, and to provide information to improve practice, a root cause analysis (RCA) was conducted for any grade 2, 3 or 4 PU developed. Cost savings were estimated based on the published cost of healing a grade 2 PU (£5241.00: Dealey et al, 2012) with adjustment for the cost of LFB and their laundering. In the first two years of the programme, unknown numbers of LFB were lost to the Trust through patients being discharged with LFB or leaving with them. To account for this, the economic calculation assumes that all LFB were retained in the Trust, and cumulative figures were used for LFB laundering. The implication is that the figures for laundering costs are over-estimated.

RESULTS

Table 1 shows the results for admissions in the Trust and the numbers and incidence of all PU and

Table 1. Admissions and incidence of all PU and avoidable heel PU over the five-year initiative

	2011	2012	2013	2014	2015	Total reductions over 5 years
Care path elements	Baseline	LFB introduced	Education introduced	New assessment tool 7/2014	Full pathway	
Incidence of all avoidable PU [overall incidence] (change versus prior year)	125 [0.059]	117 [0.052] (-6.4%)	56 [0.025] (-52.1%)	39 [0.018] (-30.4%)	41 [0.019] (+5.1%)	67%
Incidence of all avoidable heel PU [overall incidence] (change versus prior year	50 [0.024]	34 [0.015] (-32%)	11 [0.005] (-67.6%)	11 [0.005] (0%)	8 [0.004] (-27.3%)	84%
Admissions	212668	224252 (+5.4%)	220381 (-1.7%)	221905 (+0.7%)	220596 (-0.5%)	3.7%

hPU over the duration of the five-year initiative. The annual admissions during the initiative were relatively constant (~212,000-220,000), increasing slightly by 3.7% between 2011 and 2015. In 2011, 125 PU of all types was reported. hPU accounted for 50 (40%) of these. During the first year of implementation (2012) the number of all PU recorded reduced to 117, an improvement of 6.4%. The number of hPU recorded was 34 (29% of all PU), a 32% reduction over hPU in 2011.

Following the introduction of compulsory staff education and training in 2013 the total number of PUs reported was 56, a reduction of 52% compared with 2012 (*Table 1*). The number of hPUs reduced to 11 (19.6% of the total), a reduction of 67.6% versus 2012. In 2014, during which the new hPU risk assessment tool was introduced, a further reduction in total PU numbers from 56 to 39 (-30.4%) was recorded, and hPU numbers remained static, accounting for 28% of the total. A reduction in hPU (11 to 8; 27.3%) was recorded in 2015. Over the duration of the five-year initiative following implementation of the new pathway, the total number of PU reduced by 67%. Overall an 84% reduction was recorded for hPU.

In 2014 and 2015, no grade 3 and 4 hospital-acquired hPU were reported. Of the 19 patients who developed a grade 2 hPU, only three had been identified by risk assessment to have one of the 11 specified risk factors listed in the tool and had been managed using LFB according to the care standard. In two of these, RCAs identified that the patients were poorly adherent to the prescribed care plan; both patients were removing the LFB, interrupting the management of friction and shear. In the third patient who had used LFB the ulcer was deemed primarily directly related to pressure as evidence of a deep tissue injury was present. This provided an opportunity to review the application of the new tool. The remaining 16 patients with grade 2 PU were not considered at risk of hPU attributable to friction and shear and were managed according to standard practice for the risk of pressure injury. These findings suggest that ability of the hPU risk assessment tool to differentiate between patients at risk of pressure injury and those at risk of friction and shear-related injury appears to be high.

Table 2 shows the analysis of the estimated economic impact of the initiative. The annual

Table 2. Economic analysis for the new care pathway for hPU in Whiston

Year	2011	2012	2013	2014	2015
Notes	Baseline	LFB introduced	Education introduced	New assessment tool 7/2014	Full pathway + bootees
Incidence of hPU	50	34	11	11	8
Mean cost to heal / grade 2 PU (2012 figures). Note 1	£5,241.00	£5,241.00	£5,241.00	£5,241.00	£5,241.00
Total cost of PU	£262,050.00	£178,194.00	£57,651.00	£57,651.00	£41,928.00
Total LFB cost. Note 2	£0.00	£29,236.48	£6,746.88	£42,308.56	£64,130.50
Total laundry cost. Note 3	£0.00	£1,248.00	£1536.00	£3342.00	£6079.50
Total LFB + laundry costs	£0.00	£30,484.48	£8282.88	£45650.56	£70210.00
Total cost for hPU	£262,050.00	£208,678.48	£65933.88	£103,301.56	£112,138.00
Saving versus 2011	£0.00	£53,371.52	£196,116.12	£158,748.44	£149,912.00

savings versus baseline were considerable as the incidence of hPU reduced throughout the initiative. In all years the cost of acquisition of LFB, and the cost of their laundering, were significantly outweighed by the savings from the reduced incidence of hPU.

DISCUSSION

Until recently, friction leading to shear-induced tissue damage has not been adequately addressed and this may partly account for the figures on the incidence of heel PU. In addition to causing abrasions, superficial ulceration or blistering, friction applied to the skin surface can cause damaging shear stresses in deeper dermal or muscle tissue (Reger et al, 2010). Friction contributes to the development of shear stresses by tending to prevent the skin moving easily over the support surface while the rest of the patients' body moves relative to it. This is known as "static friction", also referred to as "stiction", and requires force to overcome. Practical examples include a patient moving towards the foot of the bed or the edge of the seat. The relative movement of the skin and underlying tissues causes shear stresses in the soft tissue overlying bony prominences such as the heel. Such stresses may be induced by profiling beds that increase the risk of heel friction and shearing. As the sections of the bed move to let the patients sit upright and/or to elevate the section behind the knees to reduce the likelihood of sliding down the bed the heels may move 15-20cm across the bed surface (Fletcher, 2015). Patients may also develop skin damage from the movement of the heel on bed linen when pushing themselves up the bed or in some cases by involuntary repetitive movements and/or as a result of poor manual handling techniques. Unresolved friction and shear can lead to unhealed, open wounds typically characterised as grade 2 hPU. Managing friction can protect deeper tissues from damage (Levy et al, 2015).

The NHS in the UK has instigated the Safety Thermometer, a programme of reporting PU (https://www.safetythermometer.nhs.uk/). Hospitals are statutorily required to monitor and report hospital-acquired PU creating focus on reducing their incidence. Hospital-acquired hPU are now a major focus for prevention and are managed using practices that follow guidelines recommended by NICE (2014). These include risk assessment to identify patients at risk of skin damage and the level of the risk; care planning based on the level of risk; evidence-based practice and products including pressure relief, education and training for staff; nutritional support; monitoring; reporting. The guidelines (NICE, 2014) recommend friction-reducing products where friction has been identified as a risk factor. Importantly, the author suggests that not all established risk assessment instruments include specific assessment of the heel and may miss specific patient characteristics related to friction and shear leading to the potential for damage to the heel not being recognised. The importance of the shear component of tissue damage is underpinned by the focus of a research collaboration in this area (Call and Edsberg, 2007; de Wert et al, 2015). Friction and shear are reported to be the most important factor in PU prevalence in long-term care patients in Germany (Lahmann et al, 2011; Lahmann and Kottner, 2011). Avoiding friction and shear is recommended for preventing hPU (Black, 2013; Reger et al, 2010).

The current initiative included the introduction of LFB, mandatory staff education and training in the assessment and management of risk for hPU, and development of a tool that specifically assesses the risk of hPU. In the first year of the initiative, after LFB were introduced but before the education programme was introduced, hPU reduced by 32%. The reduction may be attributed to the LFB focusing on hPU since no other change was made. The mandated training in 2013 led to a further reduction in hPU to 11 indicating the importance of specific focus and measurement. In 2014, the new risk assessment tool was introduced. The incidence of hPU remained static, perhaps indicating that the improved focused standard of care had generated the greatest returns. Thereafter the incidence reduced further in 2015 indicating that the higher standard of care overall, focusing particularly on risk assessment and prevention strategies for hPU, maintained over time, reduces hPU in at-risk patients. During 2013 and 2014 when the education and training were introduced, an intensive programme was implemented in which two TVNs trained approximately 1800 staff in one

one-hour session per week. During this time the number of hPU did not reduce. This may be because of the number of staff fully trained increased over time thereby improving the overall capability in PU management over time. It is noteworthy, however, that during this period the number of PU of all grades declined, underlining the success of the overall focus on PU. The majority of the hPU that developed during the initiative were determined to have been due primarily to pressure. In those that were shear-related, RCA suggested that non-concordance with wearing LFB was the primary reason. Alongside the reduction in 2012 compared with baseline, these findings indicate that LFB made a significant contribution to the reduction in hPU. These findings generally agree with previously published outcomes in patients managed using low friction garments (Smith and Ingram, 2010).

The reduction in hPU during the initiative led to significant savings for the Trust, an outcome also reported by Smith and Ingram (2010). In 2012 when the greatest reduction in hPU was recorded, estimated actual savings of £53,371 compared with baseline were calculated. Savings versus baseline were maintained over the entire initiative. The projected cumulative saving for the Trust between 2012 and 2015 versus 2011 was ~£558,000. If replicated over the UK NHS, annual savings would be highly significant. The economic analysis was conducted retrospectively and so has limitations. The figures for the number of LFB purchased is accurately known. However, the cost to heal a grade 2 PU is derived from published literature (Dealey et al, 2012) and the laundering cost is an estimate based on three laundry cycles per LFB at £0.50 each cycle. Individual LFB were not tracked because the additional administrative burden is too great. In the first two years of the initiative unquantified numbers of LFB were lost to the Trust. In the absence of data on the actual number of LFB in the Trust, the economic calculation assumes that all LFB remained within the Trust, and were therefore subject to laundering costs. This represents a potential upside to the overall economic analysis. No other costs were included in the analysis. Actual costs for each patient were not collected because collecting these data is not part of routine practice in the Trust. An additional economic factor that may have increased the estimated actual saving, and for which data are not available, is reduced use of fall socks. These are not required for patients wearing LFB because LFB have a non-slip section on the sole to aid transfer from the bed. The savings are therefore estimated. However, the savings are large enough not to be eliminated by small variations in input data.

The fabric used to manufacture LFB is designed to reduce the friction and therefore the associated shear associated with movement. In contrast to a range of dressings with a low CoF (Ohura et al, 2005; Call et al, 2015) and in contrast to most textiles which typically range from 0.3 to 0.7, the fabric used in LFB has a lower CoF of 0.2 (data on file, Parafricta). The fabric has low static friction, minimising the force needed to overcome skin sticking to a surface before sliding. As a result, the 'jerk' effect on skin during movement is reduced. The lower the friction especially static friction the less likely that shear forces will develop and lead to skin breakdown, thereby reducing the risk of PU. This mechanism of action differs from current methods to manage or prevent PU, which reduce or redistribute pressure.

Adding low friction materials to a standard of care that includes management of pressure and moisture has the potential to minimise the risk of tissue damage and save costs. The outcomes of the initiative to target friction and shear using LFB for hPU prevention, reported here, demonstrate the potential reduction in hPU achievable. The reduction in hPU of 84% by 2015 and associated cost savings compared with baseline was achieved by an integrated care path that included pressure relief, friction reduction, moisture management, nutrition, LFB, staff education and training and a specific risk assessment tool.

The report of the CQC assessment of the Trust in 2016 (CQC, 2016) highlighted that the Trust's new PU risk assessment tool is an area of outstanding practice. The overall programme led to a significant reduction in the number of PU of all grades on all anatomic sites, and reduced the number of hPU by a greater proportion. Clearly PU still occurred, underlining the need for continued focus and implementation of PU management practice. Further comments recognised that patient safety and positive experiences were key priorities for the Trust and underpinned all aspects of service planning and delivery. The Trust has remained below the national level for new PU reported through the NHS Safety Thermometer Audit since 2012 and continues to do so to date. Furthermore, the profile of incidence reporting versus patient harm for the Trust demonstrates that the level of reporting has increased whilst the level of harms has decreased.

CONCLUSION

The outcome of the initiative suggests that the LFB, when used in routine practice, have played a part in the reduction of hPU and in particular the decline in the proportion of hPU to PU on other sites. While general improvements in practice and awareness will have contributed to the overall incidence of grade two PU, the reduced proportion of hPU is likely to be associated with the increasing use of LFB. The value of integrating friction management into the care path was supported by the reduction in hPU in the first two years and the RCA that identified non-adherence with LFB as a key factor in the development of hPU in two patients. The reduction in hPU led to significant savings for the Trust. WUK

REFERENCES

Bååth C, Engström M, Gunningberg L, Muntlin Athlin Å (2016) Prevention of heel pressure ulcers among older patients--from ambulance care to hospital discharge: A multi-centre randomized controlled trial. *Appl Nurs Res* 30: 170–5

Black J (2004) Preventing heel pressure ulcers. *Nursing* 34(11): 17

Black J (2013) *Preventing Pressure Ulcers Occurring on the Heel*. Available at: http://bit.ly/2eXwqID(accessed 12.10.2016)

Bots ThCM, Apotheker BFG (2004) The prevention of heel pressure ulcers using a hydropolymer dressing in surgical patients. *J Wound Care* 13(9): 375–8

Call E, Edsberg LE (2007) A new initiative aiming to improve our understanding of shear force. *J Wound Care* 16(5): 209

Call E, Pedersen J, Bill B et al (2015) Enhancing pressure ulcer prevention using wound dressings: what are the modes of action? *Int Wound J* 12(4): 408-413

Cox J (2011) Predictors of pressure ulcers in adult critical care patients. *Am J Crit Care Nurs* 20(5): 364–75

CQC (2016) *St Helens and Knowsley Teaching Hospitals NHS Trust. Whiston Hospital Quality Report*. Available at: http://www.cqc.org.uk/location/RBN01 (accessed 12.10.2016)

Dealey C, Brindle CT, Black J et al (2015) Challenges in pressure ulcer prevention. *Int Wound J* 12(3): 309–12

Dealey C, Posnett J, Walker A (2012) The cost of pressure ulcers in the United Kingdom. *J Wound Care* 21(6): 261–6

de Laat EH, Schoonhoven L, Pickkers P, Verbeek AL, van Achterberg T (2006) Epidemiology, risk and prevention of pressure ulcers in critically ill patients: a literature review. *J Wound Care* 15(6):269–75

de Wert LA, Bader DL, Oomens CW, Schoonhoven L, Poeze M, Bouvy ND (2015) A new method to evaluate the effects of shear on the skin. *Wound Repair Regen* 23(6):885-90

Fletcher J (2015) Articulated bed frames and heel ulcer prevalence. *Wound Essentials* 10(1):8-12

Gefen A (2008) How much time does it take to get a pressure ulcer? Integrated evidence from human, animal and in vitro studies. *Ostomy Wound Manage* 54 (10):26–8, 30–5

Gefen A, van Neirop B, Bader DL, Oomens CW (2008) Strain-time cell death threshold for skeletal muscle in a tissue engineered model system for deep tissue injury. *J Biomech* 41(9): 2003-12

Gleeson D (2015) Pressure-ulcer reduction using low-friction fabric bootees. *Br J Nurs* 24(6): S26–9

Grey JE, Enoch S, Harding KG (2006) Pressure ulcers. *Br Med J* 332(7539): 472–5

Lahmann NA, Kottner J (2011) Relation between pressure, friction and pressure ulcer categories: a secondary data analysis of hospital patients using CHAID methods. *Int J Nurs Stud* 48(12):1487–94

Lahmann NA, Tannen A, Dassen T, Kottner J (2011) Friction and shear highly associated with pressure ulcers of residents in long-term care - Classification Tree Analysis (CHAID) of Braden items. *J Eval Clin Pract* 17(1):168-173

Langemo D (2014) *Heel Pressure Ulcer: 2014 International Pressure Ulcer Prevention & Treatment Guidelines. Panel*. Available at: http://bit.ly/2eXvcgu (accessed 12.10.2016)

Levy A, Frank MB-O, Gefen A (2015) The biomechanical efficacy of dressings in preventing heel ulcers. *J Tissue Viability* 24(1):1-11

McIntyre L (2013) A communication project to prevent pressure ulcers. *Nursing Times* 109(40): 12-15

Moore Z, Johansen E, van Etten M et al (2015) Pressure ulcer prevalence and prevention practices: a cross-sectional comparative survey in Norway and Ireland. *J Wound Care* 24(8):333-339

National Institute of Health and Care Excellence (2014) *Pressure Ulcers: Prevention and Management*. Available at: http://bit.ly/2fel1ry (accessed 4.10.2016)

National Pressure Ulcer Advisory Panel, European Pressure Ulcer Advisory Panel and Pan Pacific Pressure Injury Alliance (2014) *Prevention and Treatment of Pressure Ulcers*. Emily Haesler, ed. Cambridge Media: Perth, Australia

National pressure ulcer advisory panel (2012) *NPUAP Friction Induced Skin Injuries are they Pressure Ulcers? A National Pressure Ulcer Advisory Panel White Paper*. Available at: https://www.npuap.org/wp-content/uploads/2012/01/NPUAP-Friction-White-Paper.pdf (accessed 4.10.2016)

NHS England (2014) *Commissioning for Quality and Innovation (CQUINN): 2014/2015 guidance. http://bit.ly/2eDu6Zh* (accessed 12.10.2016)

Ohura N, Ichioka S, Nakatsuka T, Shibata M (2005) Evaluating dressing materials for the prevention of shear force in the treatment of pressure ulcers. *J Wound Care* 14(9): 401-4

Reger SI, Ranganathan VK, Orsted HL, Ohura T, Gefen (2010) *Shear and Friction in Context*. Available at: http://www.woundsinternational.com/media/issues/300/files/content_8925.pdf (accessed 28.10.2016)

Smith G, Ingram A (2010) clinical and cost effectiveness evaluation of low friction and shear garments. *J Wound Care* 19(12):535-542

Vowden K (2012) *Pressure Ulcer Prevention and Management Policy and Educational Resource Book. Bradford Teaching Hospitals NHS Trust*. Available from http://bit.ly/2eDttP6 (accessed 4.10.2016)