Chapter 1

1.1 Background

In the United Kingdom (UK), major trauma affects 20,000 people each year, with approximately 500-600 people going on to sustain injuries to the spinal cord (National Institute of Clinical Excellence (NICE), 2012) costing the National Health Service (NHS) between £0.3 billion and £0.4 billion annually (National Audit Office, 2009).

A Spinal Cord Injury (SCI) is damage to the spinal cord, half of the fractures that cause SCI involve fractures of the cervical spine (Spinal Injuries Association, 2009). SCI's commonly affect young adults and common causes of SCI are owed to road traffic collisions, falls, sports and domestic violence (British Medical Journal, 2017). Mortality is highest during the initial year following the injury and increases with the injury level and severity (World Health Organisation (WHO). 2013). Additionally, secondary conditions caused by SCI such as respiratory dysfunction, pulmonary infections and suicide are also factors that attribute to SCI long term (Hagen et al. 2010).

Current UK Ambulance guidelines follows an immobilisation algorithm (appendix A) stating if immobilisation is indicated then the whole spine should be immobilised using an orthopaedic scoop stretcher, head restraints and a cervical, rigid collar, thus providing the best possible outcome (Brown et al, 2016). Emphasis on cervical immobilisation was established in the 1960's as it was estimated during the 1960's that cervical spine injuries produced 40% of neurological deficit, collar placement was subsequently introduced as teaching objectives for paramedics and other ambulance staff (Poldolsky et al. 1983).

1.2 Rationale

The current use of cervical collars is an area of recent debate in the paramedic profession. Initially considered harmless and used as a precautionary measure however, there is an increasing amount of evidence suggesting otherwise (Rogers. 2017) with literature arguing that collars cause more harm than good and should not be used (Sundstrøm et al., 2014). Therefore, it can be debated if the practice of using them is still consistent with the principles of patient safety, and evidence-based practice as stipulated within the Healthcare Professionals Council Standards of Proficiency for Paramedics (HealthCare Professionals Council (HCPC), 2014).

1.3 Aim

This literature review will aim to comprehensively examine research surrounding the adverse effects of cervical collars and the range of movement they enable, gaining a comprehensive understanding of their efficacy.

Chapter 2: Critical Review of the Literature

2.1 Adverse Effects

Clinical decision-making must incorporate ethical considerations, to act in the patient's best interest and do no harm (Willis and Mehmet. 2015), additionally a clinician must recognise the limiting effects of interventions (HCPC, 2014). Evidence has suggested that cervical collars produce adverse effects (Rogers. 2017), the first theme identified in this literature review.

Despite the assumed beneficial effect of spinal immobilisation, evidence suggests that immobilisation is associated with dangerous adverse effects (Duncan, 2016). Using a retrospective study design over five years where spinal immobilisation was applied to 96.3% of 1082 patients, Oosterwold et al. (2016) researched the incidence of possible adverse effects through spinal immobilisation in the pre- hospital setting. This timeframe affords a large sample size and is therefore considered representative of the population (Ellis, 2016).

Expecting to see comparable results to Kwan et al. (2005) whereby 55% of healthy volunteers complained of moderate to severe pain within 30 minutes of spinal immobilisation, pain was documented in 0.9% of patients in Oosterwold et al. (2016) study. Possible explanations for this discrepancy were on scene times were shorter than 30 mins (Oosterwold et al. 2016), despite the mean total time from initial contact to hospital arrival was calculated at 49.13 minutes. However, Standard Deviation (SD) was determined to be 16.25, this indicates times were dispersed and could have been much longer or shorter than the mean average, lessoning the validity of the study (Aveyard, 2014). Another explanation suggested adverse effects were not documented on paperwork causing this discrepancy (Oosterwold et al. 2016).

Additionally, 75 patients (6.9%) showed signs of increased intracranial pressure (ICP) conceivably produced by venous compression in the neck causing brain swelling (Hunt et al. 2001). However, despite Prehospital Trauma Life Support (PHTLS) (National Association of Emergency Medical Technicians (U.S.) & American College of Surgeons, 2016) guideline recommendations, removal of the rigid cervical spine collar wasn't carried out (Oosterwold et at. 2016). A lack of awareness and non-explicit documentation of removal could account for this, further decreasing the validity of the study (Oosterwold et al. (2016). Oosterwold et al. (2016) deduced adverse effects through pain and increased ICP were caused by a cervical collar, prompting discussions of a lack of awareness to guideline recommendations, additionally, Oosterwold et al. (2016) inferred clearance needs to be a priority to minimise time in the collar thus preventing adverse effects.

Whilst Oosterwold et al. (2016)'s research design studied the incidence of adverse effects Ham et al. (2016) study outcome focussed specifically on Pressure Ulcers (PU's) and associated pain. Despite protecting the possibly injured spine, the risk of pressure ulcer development and is pain increased by short-term pressure on the skin, as identified in the study conducted by Ham et al. (2016).

PU's and pain were dependent variables, whilst using independent variables, including Glasgow Coma Score (GCS), gender and age, to explore associations (Ham et al. (2016). Investigating the independent variables, or exposure, on the dependent variable, or outcome, creates discussion of what causes an effect (Ellis, 2016).

Ham et al. (2016) used a large patient sample of 342 following emergency department (ED) admission with a suspected SCI, although smaller than Oosterwold et al. (2016) study, however, a sizeable proportion of patients weren't included in the study, possibly distorting the results and consequently decreasing the validity of the study (Aveyard, 2014).

PU's were present in 78.4% of patients after removing the cervical collar and head blocks whilst at least one severe indentation mark was observed in 28.1% of patients. PU's were categorised using the National Pressure Ulcer Advisory Panel Guidelines, (2009 (appendix K). Values all presented within the 95% confidence levels, indicating that these results were not due to chance strengthening the validity of the study (Aveyard, 2014).

PU's cause pain and affect physical, social, psychological and financial aspects of living depending on the severity (Gorecki, 2009). Whilst category 1 PUs are reversible, there is a risk of increased severity developing (National Pressure Ulcer Advisory Panel, European Pressure Ulcer Advisory Panel and Pan Pacific Pressure Injury Alliance. 2014) making prevention vital. To evaluate pain Ham et al. (2016) used the Numerical Rating Scale (NRS) (Appendix L). NRS provides a subjective feeling of intensity of pain whilst measuring discomfort and grading impact of pain on function (Breivik et al. 2009). Pain was experienced in 63.2% of patients, and 38.5% experienced severe pain.

There is an assumption that pressure causing severe pain results in distress, necessitating movement to relieve pain and pressure indicating that high pain scores potentially impede the main purpose of the cervical collar (Ham et al. 2016). Protecting the spine from further injury must therefore be a priority, to minimise adverse outcomes and further complications (Ham et al. 2016). Prioritising clearance of the spine thus minimises time in a cervical collar, however, safer alternatives to the cervical collar needs to be found, taking into consideration different morphological aspects (Ham et al. 2016).

March et al. (2002) used a single blinded prospective study on 20 healthy volunteers thus avoiding the placebo effect whereby healthy participants experience a variance in theoretical expectations (Booth et al. 2013). The study used convenience sampling, the least time intensive and least expensive type of sampling, lending itself to a small sample size and typically underrepresents certain sociodemographic groups as participants are chosen based on accessibility (Bornstein et al. 2013). Thus, providing a false representation of the population (Aveyard, 2014).

Subjects were fully immobilised for 60 minutes using a cervical collar, wooden backboard and straps. They subjectively rated their back pain every 5 minutes using the NRS pain scale (Appendix L). Furthermore, subjects were rolled, their vertebrae palpated to elicit midline tenderness and asked if they had any pain on palpation every 10 minutes March et al. (2002). Whilst this research aims to understand individual experience to establish a participant view point, a description of qualitative research (Williams, 2012), the study examines the variable of time to answer the question, involving the use of statistics to analyse data identifying it as quantative (Booth et al. 2013).

The outcome demonstrated a statistically significant increase with p=0.0001 over 60 minutes. A p value infers the probability that the hypothesis is true and statistically significant, if p= <0.05 there is less than a 5% probability that this relationship arose by chance (Cutter. 2012). However; analysis between the two halves of the study showed a significant statistical change in the first 30 minutes (p=0.0001) whereas the latter half showed no significant change (*p*=0-1294). This suggests pain is time dependent and immobilised patients' needs immediate assessment immediately on admission to the ED to prevent pain developing (March et al. 2002). The back board was the presumed cause of iatrogenically induced midline vertebrae pain (March et al. 2002), Conner et al. (2013) states the back board should be used exclusively as an extrication device and not for conveying. Therefore, the orthopaedic scoop could have resolved the iatrogenically produced midline point tenderness (March et al. 2002).

Whilst this study finds a significant increase in pain during the first 30 minutes identifying clearance as a priority, the study had limitations. The use of a backboard, an out of date practice, could distort the conclusions and relevance to practice, lessoning the strength of the study. Whilst protecting the spine is the priority, adverse effects can be detrimental to a patient's outcome (Ham et al. 2016).

Length of time in the collar, was identified as a cause of pain (Ham et al. 2016; March et al. 2002 and Oosterwold et al. 2016) and clearance needs to be a priority to minimise time in the collar. Pain was most prevalent in the initial 30 minutes in a cervical collar (March et al. 2002) whilst this study uses out of date techniques it does carry an important consideration. Vincent-Lambert and Mottershaw, (2017) substantiates that lengthy on scene times need to be addressed concluding that prolonged on scene time could negatively impact patient outcome. Whilst Oosterwold et al. (2016) findings could be argued due to inaccuracies in documentation the study found a life-threatening adverse effect included raised ICP when a cervical collar is in situ (Oosterwold et al. 2016) raising the discussion of awareness and knowledge of pre-existing guidelines to reduce adverse effects.

Ultimately practice needs to be challenged to minimise adverse outcomes becoming detrimental with an emphasis on finding safer alternatives to provide a better fit (Ham et al. 2016) and clinicians must be able to recognise full immobilisation may not be suited to a generic guideline to avoid adverse effects and not all patients with suspected SCI need to be fully immobilised (Theodore et al, 2013)

2.2 Range of Movement

As previously discussed spinal immobilisation comprises three elements; orthopaedic stretcher, head blocks and cervical collar (Brown et al. 2016).
Owing to the uncertainty of how much movement is permissible when a SCI is suspected ideal immobilisation should inhibit movement (Houghton and Driscoll. 1999). Raising the discussion of range of movement when a cervical collar is in place.

Aiming to study the efficacy of collars by evaluating the effect of head blocks with and without collars and the effect of incorrectly sized collars Houghton and Driscoll (1999) used 24 healthy subjects, comparable to the adverse effect study of March et al. (2017). However, using healthy volunteers with a small sample study doesn't provide a true representation of the population, decreasing the validity of the study (Aveyard, 2014). Of the 24 participants recruited from a hospital 15 were male, exhibiting a representative sample of the general population as SCI affects 81% of males (British Medical Journal, 2017).

Subjects were immobilised on a long spinal board in addition to the cervical collar and asked to actively move their head as far as possible in flexion, extension, lateral flexion, left, right, and both left and right rotation (Houghton and Driscoll. 1999). A repeated measures design was used to assess Range of Movement (ROM) of collar alone, with the addition of head blocks and replicated again with ill-fitting collars in the same order each time (Houghton and Driscoll. 1999) thus maintaining consistency.

Two subjects were unable to have larger ill-fitting collars applied as they were already at the maximum size. In these cases, values obtained were reproduced using the technique known as last value carried forward, filling in data based on existing data, using this technique can lead to bias. However, Houghton and Driscoll. (1999) felt that if these results were omitted the findings would be less significant and therefore considered acceptable. Results indicated that collars only restrict movement by 30-40%, head blocks increased 20-30% restriction and collars alone restrict movement but do not achieve total immobilisation (Houghton and Driscoll. 1999). The study's age meant some practices are outdated, the long board is no longer used in practice but has been replaced by the orthopaedic stretcher (Brown et al. 2016), however, the use of hard collars seen in this study are still being used thus demonstrating its relevance to current practice.

As immobilisation is essential in extrication and transport prehospitally, poorly fitting cervical collars can be detrimental, allowing movement and reducing immobilisation (Houghton and Driscoll. 1999). Therefore, Houghton and Driscoll (1999) determined the use of collars should be supported with head blocks to increase immobilisation, a statement supported by Theodore et al. (2013) who states a combination of a cervical collar and head blocks is effective for spinal immobilisation.

Holla (2011) carried out a similar study to Houghton and Driscoll (1999) by measuring the ROM when a cervical collar was used with head blocks over 4 planes to carry out a proof of principle study observing the active ROM. Using 10 healthy volunteers, a smaller sample size to Houghton and Driscoll (1999) study, it was determined that increasing the number of participants in this study would not affect the outcome as using the best cervical immobiliser governs the ROM (Holla, 2011). However, the outcome of this study cannot be transferred generally across the population as no obese or short participants were used consequently lessoning the validity of the study (Aveyard, 2014).
Statistically the difference in the ROM with the collar was significantly reduced compared to no collar ($p<0.005$). Additionally, a significant decrease in the ROM when head blocks were compared with the rigid collar ($p=0.005$) with no significant decrease combining the rigid collar and head blocks ($p>0.05$) (Holla, 2011). Research by Poldolsky (1983) previously suggested sand bags used as head blocks and tape was more effective than any collar. Holla (2011), using modern accurate testing, supports Poldolsky's (1983) study and quashes the assumption that using a combination of head blocks and cervical collars results in the best immobilisation. Furthermore, whilst the aim of a cervical collar is to restrict movement Holla (2011) found that the range of mouth opening was significantly reduced, thus compromising the airway making the use of adjuncts and maintaining a patent airway difficult (Kwan et al, 2009).

Holla, (2011) concluded rigid cervical collars do not provide any significant additional immobilisation to head blocks whereas using one can create adverse effects, as previously discussed in the first theme, consequently the combination of hard collars and head blocks should be reconsidered.

Whilst Houghton and Driscoll (1999), Holla, (2011), and Bell et al. (2009) used healthy participants, Horodyski et al. (2011) used cadaver models to determine the extent cervical collars immobilise the spine with and without stability using no collar as the control. Cadavers limit the study by negating the natural ability of an alert patient to splint their neck with muscle tone (Horodyski et al. 2011), therefore, ROM had to be induced by a third party. Testing was carried out on an intact spine before instability was created at C5-C6. Comparable to the other studies a repeated measures design was used with all movements repeated twice on each cadaver. As multiple comparisons were included the Bonferroni adjustment was used. Thus, reducing the chances of obtaining false-positives when multiple pair tests are carried out as more hypotheses are being tested, limiting the probability of identifying at least one significant result due to chance (Napierala. 2012).

Results identified significantly more motion when the spine was unstable in all measures except extension where although the extension measurement was greater in the unstable spine it was not statistically different (p=0.59). In the unstable spine there was no significant difference between the collars and no collars, however the collars did restrict motion (Horodyski et al. 2011). Flexion with the collars in place was 17-41% of the control range and whilst flexion did occur the collars reduced it by 30-40 degrees in comparison to no collar, this was similar amongst all the collars and each plane of movement (Horodyski et al. 2011). Horodyski et al. (2011)

deduced conscious, alert patients deliver internal stability using normal muscle tone and strength through pain inducing a stabilising effect. An assumption supported by (Benger and Blackham, 2009) who concluded that an alert, stable and co-operative patient does not need to be immobilised. However, those with a reduced level of consciousness and unable to protect their own cervical spine, immobilisation is an appropriate level of protection (Benger and Blackham, 2009).

Ultimately the cervical collar cannot be expected to implicitly immobilise a cervical spine but should be used alongside other spinal immobilisation techniques for effective stabilisation to take place (Horodyski et al. 2011).

Whilst Holla (2011), Houghton and Driscoll (1999) and (Horodyski et al. 2011) all looked at the effectiveness of properly fitted cervical collars Bell et al. (2009) looked at the ROM in poorly fitted collars. The rationale behind this study being the optimal testing conditions seen previously do not offer a realistic representation in the emergency clinical setting (Bell et al. 2009). Sundstrøm et al. (2014) support this suggesting many collars are not fitted correctly prehospitally. To carry out the study Bell et al. (2009) used 12 healthy males, with no history of previous spine injuries, and mean age of 29.44 (SD 6.598 years), comparable to Houghton and Driscoll's (1999) study whose average age was 27, these ages are reflective of the general population identifying that almost half of patients are aged between 16 and 30 (BMJ, 2017). Whilst males are more likely to sustain a traumatic SCI (BMJ, 2017) having an all-male study isn't a true representation of the population.

Like the previous studies a repeated measures design was used, with the collar applied correctly, one size too big and one size too small. The motion resembling everyday life by moving as far as possible without pain and discomfort and the student *t* test used where *p*=<0.5 to determine significant difference (Bell et al. 2009). Results showed in all primary motions the correctly sized collar allowed less motion than the incorrectly sized collars (Bell et al. 2009). Significant differences were seen in axial rotation and right lateral bending as well as in extension using the too big collar and left lateral bending in the too small collar.

Whilst it is argued even a correctly fitted collar can produce up to 30 degrees of motion (Benger and Blackham, 2009*)*, a patient wearing an incorrectly sized cervical collar could experience added cervical impairment due to lack of restriction and under restrained motion of the neck creating significant clinical implications (Bell et al. 2009). It is estimated 3-25% of SCI occur following the initial trauma through secondary injuries (Askins and Eismont, 1997) although it is unknown how many secondary SCI's have been prevented from cervical immobilisation (Sundstrøm et al, 2014). Using healthy subjects in this study is not representative of the injured population where movement is discouraged. However, this model of maximum exertion could represent conditions experienced through involuntary motions leading to secondary injury (Bell et al. 2009). There is a similar discussion brought up in Horodyski et al. (2011) study in which maximum ROM is never established on a patient in the hospital or pre-hospital setting, instead the study tested the collars on restriction of movement as a source of protection.

Whilst immobilisation is essential in preventing secondary injury (Houghton and Driscoll. 1999) an argument is raised over whether cervical collars achieve this. Additionally, Bell et al. (2009) study raises a sound discussion that cervical collars applied prehospitally may be incorrectly sized creating substantial clinical implications and detrimental effects for unconscious patients, whilst conscious patients are able to deliver internal stability using normal muscle tone and strength (Horodyski et al. 2011). Nevertheless, all studies corroborate that cervical collars restrict movement, but do not implicitly immobilise a cervical spine. Horodyski et al. (2011) suggests using collars alongside other immobilisation techniques. Whilst in contrast Holla (2011) suggests rigid cervical collars do not provide any significant additional immobilisation to head blocks, creating adverse effects and consequently should be reconsidered and a more appropriate technique is required to immobilise the cervical spine.

Chapter 3: Conclusion

3.1 Conclusion

The use of cervical collars are an accepted form of cervical immobilisation, prominent in prehospital treatment in managing the suspected SCI in the UK. However, recent evidence suggests cervical collars cause more harm than good and contradict UK Ambulance Guidelines for spinal immobilisation.

Theme one identified that time in a cervical collar needs to be minimised to prevent adverse effects, however the studies can be questioned owing to inaccuracies and using out of date practise potentially skewing the results. Importantly the studies failed to discuss the more severe adverse effects that can affect patient outcome. However, the argument of identifying worsening signs and symptoms with a cervical collar in place were presented.

The second theme of range of movement discussed whether a cervical collar achieves immobilisation using a combination of living participants and cadavers but no real patients. An immediate weakness of the studies included were the sample size however it was determined in one study that increasing the number of participants would not affect the outcome as using the best cervical immobiliser governs the ROM. Nevertheless, all studies corroborated that cervical collars restrict movement but do not implicitly immobilise a cervical spine.

3.2 Limitations

The articles comprised quantative studies only suggesting a lack of comprehensive and varied research weakening the conclusions. As such further research, preferably

RCT's to compare alternative immobilisation techniques, as well as qualitative studies, are required to overcome this to establish further evidence-based guidelines in the pre-hospital setting. However, the range of locations, sample sizes, time frames used, and methodologies strengthens the conclusions. A limitation in some of the studies included a weakness of evidence in documentation which were highlighted throughout.

3.3 Implications and Recommendations for Practice

Given that cervical collars do not provide any significantly increased additional immobilisation and the adverse effects of a cervical collar can be detrimental to patients. UK Ambulance Guidelines need to re-consider the evidence presented within this review, and specifically look at the removal of cervical collars from prehospital practice.

References

Askins, V. and Eismont, F. (1997). *Efficacy of Five Cervical Orthoses in Restricting Cervical Motion*. Spine, 22(11), pp.1193-1198.

Aveyard. H, (2014). Doing a Literature Review in Health and Social Care. 3 ed. Open University Press. Berkshire.

Bell, K., Frazier, E., Shively, C., Hartman, R., Ulibarri, J., Lee, J., Kang, J. and Donaldson, W. (2009). *Assessing range of motion to evaluate the adverse effects of ill-fitting cervical orthoses*. The Spine Journal, 9(3), pp.225-231.

Benger, J. and Blackham, J. (2009*). Why Do We Put Cervical Collars On Conscious Trauma Patients?.* Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine, 17(1), p.44.

Booth. A, Papaioannou. D, and Sutton. A, (2013), *Systematic Approaches to a Successful Literature Review*, 1st Ed, London, Sage.

Bornstein, M., Jager, J. and Putnick, D. (2013). *Sampling in developmental science: Situations, shortcomings, solutions, and standards.* Developmental Review, 33(4), pp.357-370.

Breivik. H, Borchgrevink. P, Allen. S, Rosseland. L, Romundstad. L, Breivik Hals. E, Kvarstein. G, Stubhaug. A, (2008) *Assessment of pain*, BJA: British Journal of Anaesthesia, 101(1), pp 17–24.

British Medical Journal (2017) *Chronic spinal cord injury*. Available at: http://bestpractice.bmj.com/best-practice/monograph/1176/basics/epidemiology.html (Accessed: 6 July 2017).

Brown, S. N., Kumar, D., Millins, M., & Mark, J. (2016). *UK ambulance services clinical practice guidelines 2016*. Bridgwater: Class Professional.

Connor. D, Greaves. I, Porter. K, and Bloch. M, (2013), *Pre-hospital spinal immobilisation: an initial consensus statement.* Emerg Med J 2013;30: 1067–1069.

Critical Appraisal Skills Programme (2017). *CASP Checklist*. [online] Available at: http://www.casp-uk.net/casp-tools-checklists. (Accessed: 17 September 2017).

Cutter. J (2012). In; *Quantative research in paramedic practice: an overview*. In; Griffiths, P. and Mooney, G. (2012) *The paramedic's guide to research*. Maidenhead: McGraw-Hill/Open University Press.

DeVivo, M. (2012). *Epidemiology of traumatic spinal cord injury: trends and future implications*. *Spinal Cord*, 50(5), pp.365-372.

Duncan, M (2016*) Spinal Immobilization Adverse Effects vs. Benefits in the Trauma Patient,* School of Physician Assistant Studies. 596.

Ellis. P (2016). *Understanding Research for Nursing Students*. 3rd Ed. Sage. London.

Garrard, J., 2007. *Health sciences literature review made easy: The matrix method*. 5 Ed. Jones & Bartlett Learning

Gorecki, C., Brown, J., Nelson, E., Briggs, M., Schoonhoven, L., Dealey, C., Defloor, T. and Nixon, J. (2009). *Impact of Pressure Ulcers on Quality of Life in Older Patients: A Systematic Review. Journal of the American Geriatrics Society*, 57(7), pp.1175-1183.

Hagen, E., Lie, S., Rekand, T., Gilhus, N. and Gronning, M. (2010) "*Mortality after traumatic spinal cord injury: 50 years of follow-up*", Journal of Neurology, Neurosurgery & Psychiatry, 81(4), pp. 368-373.

Ham, W., Schoonhoven, L., Schuurmans, M. and Leenen, L. (2016). *Pressure ulcers, indentation marks and pain from cervical spine immobilization with extrication collars and headblocks: An observational study*. Injury, 47(9), pp.1924-1931.

Healthcare Professions Council (HCPC), (2014) *Standards of Proficiency; Paramedics* [PDF] Available at: http://www.hpc-uk.org/assets/documents/1000051CStandards_of_Proficiency_Paramedics.pdf [Accessed 18 Dec. 2017].

Horodyski, M., DiPaola, C., Conrad, B. and Rechtine, G. (2011). *Cervical Collars are Insufficient for Immobilizing an Unstable Cervical Spine Injury*. The Journal of Emergency Medicine, 41(5), pp.513-519.

Houghton. L, and Driscoll. P, (1999), *Cervical Immobilisation – Are We Achieving it? Pre-Hospital Immediate Care*, 3, pp.17-21.

Holla, M. (2011). *Value of a rigid collar in addition to head blocks: a proof of principle study*. Emergency Medicine Journal, 29(2), pp.104-107.

Hunt. K, Hallworth. S and Smith. M, (2001) *The effects of rigid collar placement on intracranial and cerebral perfusion pressures*, Anaesthesia, 56, pp. 511-513.

Kwan I, Bunn F (2005). *Effects of prehospital spinal immobilization: a systematic review of randomized trials on healthy subjects*. Prehosp Disaster Med. 20(1):47–53.

Kwan I, Bunn F, Roberts IG (2009) *Spinal immobilisation for trauma patients.* Cochrane Database Syst Rev (2)

March, J., Ausband, S. and Brown, L. (2002). *Changes in physical examination caused by use of spinal immobilization*. Prehospital Emergency Care, 6(4), pp.421-424.

Mooney. G (2012). In; *Conducting a Critical Literature review in Paramedic Practice*. In; Griffiths, P. and Mooney, G. (2012) *The paramedic's guide to research*. Maidenhead: McGraw-Hill/Open University Press.

Napierala. C, (2012), *What Is the Bonferroni Correction?* [Online] Available at: https://www.aaos.org/AAOSNow/2012/Apr/research/research7/?ssopc=1[Accessed 18 Dec. 2017].

National Association of Emergency Medical Technicians (U.S.), & American College of Surgeons. (2016). *PHTLS: prehospital trauma life support.* 7 Ed. Burlington, MA : Jones & Bartlett Learning.

National Audit Office (2009). *Major trauma care in England*. available at: https://www.nao.org.uk/wp-content/uploads/2010/02/0910213es.pdf (accessed 6 July 2017).

National Collaborating Centre for Methods and Tools (2017). Critical *appraisal tools to make sense of evidence | Resource Details | National Collaborating Centre for Methods and Tools*. [online] Available at: http://www.nccmt.ca/knowledge-repositories/search/87 [Accessed 18 Dec. 2017].

National Institute for Health and Care Excellence (NICE), (2012). *Spinal injury assessment: assessment and imaging and early management for spinal injury (spinal column or spinal cord injury).* Available at: https://www.nice.org.uk/guidance/ng41/documents/spinal-injury-assessment-final-scope2 (Accessed: 6 July 2017).

National Pressure Ulcer Advisory Panel, European Pressure Ulcer Advisory Panel and Pan Pacific Pressure Injury Alliance. (2014). *Prevention and Treatment of Pressure Ulcers: Clinical Practice Guideline*. Cambridge Media: Osborne Park, Western Australia.

National Pressure Ulcer Advisory Panel. (2009) *Prevention and Treatment of Pressure Ulcer: Quick Reference Guide.* Washington D.C.

Oosterwold, J., Sagel, D., van Grunsven, P., Holla, M., de Man-van Ginkel, J. and Berben, S. (2016). The characteristics and pre-hospital management of blunt trauma patients with suspected spinal column injuries: a retrospective observational study. *European Journal of Trauma and Emergency Surgery*, 43(4), pp.513-524.

Podolsky. S, Baraff. I, Simon. R, Hoffman, J, Larmon. B. and Ablon, W. (1983) *Efficacy of Cervical Spine Immobilization Methods*, The Journal of Trauma: Injury, Infection, and Critical Care, 23(6), pp. 461-465.

Rogers. L, (2017), *No place for the rigid cervical collar in pre-hospital care*. International Journal of Paramedic Practice, 7(3), pp. 12-14.

Spinal Injuries Association (2009). *Preserving and developing the National Spinal Cord Injury Service: Phase 2—seeking the evidence. Research Report* Milton Keynes:. Available at: https://www.spinal.co.uk/wp-content/uploads/2015/07/234-590487.pdf (Accessed: 6 July 2017).

Sundstrøm, T., Asbjørnsen, H., Habiba, S., Sunde, G. and Wester, K. (2014). *Prehospital Use of Cervical Collars in Trauma Patients: A Critical Review*. Journal of Neurotrauma, 31(6), pp.531-540.

Theodore, N., Hadley, M., Aarabi, B., Dhall, S., Gelb, D., Hurlbert, R., Rozzelle, C., Ryken, T. and Walters, B. (2013). *Prehospital Cervical Spinal Immobilization After Trauma*. *Neurosurgery*, 72, pp.22-34.

Vincent-Lambert. C, and Mottershaw. T (2017). Views of Emergency care providers about factors that extend on scene time intervals. African Journal of Emergency Medicine.

Williams, (2012) In; *Quantative research in paramedic practice: an overview*. In; Griffiths, P. and Mooney, G. (2012) *The paramedic's guide to research*. Maidenhead: McGraw-Hill/Open University Press.

Willis. S and Mehmet. N (2015) In; Legal and Ethical Aspects of Paramedic Practice. In; Willis. S and Dalrymple. R (2015). *Fundamentals of Paramedic Practice A Systems Approach*. Sussex. John Wiley & Sons.

World Health Organization *(WHO) (2013) Spinal cord injury Factsheet No 384*, [Online] Available at: http://www.who.int/mediacentre/factsheets/fs384/en/ (Accessed: 6 July 2017).