AN ANATOMICAL STUDY OF THE NERVES TARGETED FOR SENSORY BLOCKS OF THE HEAD AND NECK IN NEONATES AND INFANTS

Lané Prigge

Submitted to comply with the requirements of the degree:

Ph.D. (Anatomy)

In the school of Medicine, Faculty of Health Sciences,
University of Pretoria, Pretoria, South Africa

2014 – 2018

Supervisors: Prof AN van Schoor
Prof AT Bosenberg

The financial assistance of the National Research Foundation (NRF) towards this research is hereby acknowledged. Opinions expressed and conclusions arrived at, are those of the author and are not necessarily to be attributed to the NRF.

Declaration

I declare that the dissertation that I am hereby submitting to the University of Pretoria for the PhD degree in Anatomy, is my own work and that I have never before submitted it to any other tertiary institution for any degree.

Lané Prigge

6 April 2018

Acknowledgements

At the end of this journey, I would like to start at the biggest and most important, our Heavenly Father. Without the patience and motivation He instilled in me, this thesis would not have been completed. Then for the following people with whom I am blessed in my life, and would like to say a special word of thanks:

- Firstly, to the families of the cadaveric donors used in this research, I would like to extend a heartfelt word of thanks. Thank you for the selfless act of allowing us to utilise your loved ones in the search for answers. Through your contribution to science, we hope to achieve a better future for the patients to follow.

- Mr E de Jager and Miss T Nadesan, who assisted me when I needed an extra set of hands.

- Niels Hammer, Thomas Wolfskämpf and Hanno Steinke, the three gentlemen at University of Leipzig, Germany, who not only showed me a different side of anatomy, but also a deeper side of myself. You took me out of my depth, and taught me so much, and I thank you for it.

- Mrs Joyce Jordaan and Dr Liebie Louw for all the statistical analyses that were done in this thesis. Thank you for always having the patience to explain concepts to me, and always being willing to help beyond what is required of you. You greatly assisted me, and for that I am extremely thankful!

- Prof Albert van Schoor and Prof Adrian Bosenberg, who stood by my side and supported me tremendously with this thesis. Thank you for all the advice and guidance you gave me, as well as the hard work, long hours and efforts you put into this thesis.

- My friends and colleagues from the Department of Anatomy, University of Pretoria, as well as Department of Anatomy, Sefako Makgatho Health Sciences University. Without your support and encouragement I would not have been able to complete this thesis. You often had to assist in my responsibilities while I attempted to conduct my research or complete my write-up. I appreciate your love and support more than I can say. To the ones starting out with their PhD's, Nkhensani, Gerda, Reinette, Soné, Daniele and Suvasha, good luck with your dissertations, and remember to keep going! Hopefully I can assist and motivate you as much as you had done with me!

- Barbara Viljoen, thank you for all your assistance and patience. Without your knowledge and guidance, this would not have been a project of which I am proud!

- A very special thank you to one of my biggest mentors and advocators, Mr Henry Human. Not only did you create a safe environment for me to flourish in, but also your motivation, constant encouragement and interest, kept me going at times when things got tough! I will forever treasure the role you played in my life, my education and my endeavours to be the best person (and anatomist) I can be!

- To all my family and friends who supported me: You did not just motivate and encourage me, but you ensured that life did not get me down. During all of the years, your concerns, your interest, your love and support did not go unnoticed. Without your motivation and somewhat “relentless pushing”, I would not have been able to complete this thesis!

- To Esmé and Christi, you are both too young to know about mommy sitting working at night, working on a sample that made her cry, and maybe even neglecting you in order for her to complete this research project. I did all of this for you. Not only to help you (should the situation arise), but to make you proud of me. I will endeavour to be an example for you and to encourage you to chase your goals and dreams, knowing that whatever life throws at you, you can overcome. Reach for the sky!

- To the most important person in my life, my husband, Waldo: You are the first one I called when my dissections got me emotional, the first one that I phoned out of excitement the moment I e-mailed my last chapter to Albert. You motivated me late evenings when I was reluctant to write and the one who, after each day, told me how proud you are of me. You assisted me with data capturing while attending to our young daughter at that stage, and who never made me feel guilty for being an educator and researcher. You are the best thing that ever happened to me, and I cannot thank God enough for blessing me with a husband like you. Without you, I would not be the mother, wife or person that I am, and I thank you for that!

Summary

An anatomical study of the nerves targeted for sensory blocks of the head and neck in neonates and infants

L Prigge

Supervisors: Prof AN van Schoor, Prof AT Bosenberg

Department of Anatomy: Clinical Anatomy, School of Medicine, Faculty of Health Sciences, University of Pretoria, South Africa

The father of modern regional anaesthesia, Gaston Labat, made this very important statement: “Anatomy is the foundation upon which the entire concept of regional anaesthesia is built. Anyone who wishes to be an expert in the art of regional anaesthesia must be thoroughly grounded in anatomy.” This statement is as true today, as in 1922 when it was first made. Adult anatomy applicable to regional anaesthesia has been extensively investigated, resulting in the improvement of techniques and a decrease in complications. However, in the paediatric population, in most cases, the anatomy of adults are used and disproportionately modified in order to perform paediatric regional anaesthetic techniques. This is not considered favourable, and can lead to failed blocks or complications. Therefore, knowledge of the anatomy of paediatric patients is not only required, but considered vital for the successful performance of regional nerve blocks in paediatric patients. The overall aim of this research study was, therefore, to effectively describe the paediatric anatomy of five head and neck nerve blocks commonly performed, based on dissections and measurements of paediatric formalin-fixed cadavers, as well as osteological samples. Based on easily identifiable bony~ and soft tissue landmarks, easily performed techniques are proposed in order to safely and successfully perform these regional nerve blocks in paediatric patients. This will not only minimise possible opioid-related complications, but will ensure optimal management of postoperative pain. In conclusion, the importance of anatomical knowledge applicable to the paediatric population is beyond discussion, and techniques based on the applicable neonatal and infant anatomy will not only educate and facilitate doctors during the performance of these regional nerve blocks, but will also greatly benefit the paediatric patients undergoing these procedures.

Keywords: Paediatric, Regional anaesthesia, Greater occipital, Superficial cervical plexus, Periorbital, Maxillary nerve

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1 Regional anaesthesia in overview

1.1 Introduction

1.1.1 Regional anaesthesia in paediatric patients

Over the past several years, a renewed interest has been observed in the field of regional anaesthesia for paediatric patients (Giaufré *et al*., 1996). This is due to the increased survival of extremely premature infants, and infants with congenital malformations and life-threating conditions. However, this was achieved by exposing these infants to multiple stressors in the neonatal period (Grunau *et al.,* 2006). Berde and colleagues (2005) echo this statement by affirming that neonates can often undergo urgent intervention during their initial days and weeks of life.

Several studies on the effects of neonatal pain have been published. In a study conducted by Taddio and co-workers (1995), the pain response of male infants who underwent neonatal circumcision, was evaluated during routine vaccinations. They conclude that male infants, who had previously undergone circumcisions, exhibited a greater pain response than those who did not. In a similar study, they state: “This initial analysis raised concerns about the possible long-term effects of untreated pain in infants, especially those who have repeated experience of pain”.

Simons and collaborators (2003) make the following comment in their research study on pain inflicted on newborn babies: “In sharp contrast of the accumulating evidence that repetitive pain is harmful in newborns, and despite major clinical advances over the past 10 years, neonates experience up to 14 painful procedures per day, and, remarkably, more than 65% of the patients in this study did not receive appropriate analgesic therapy”.

Parry (2008) confers that it is widely known that neonates experience pain based on their cortical awareness, as well as their incomplete development of inhibitory pathways. Short-term and long-term detrimental effects will occur due to the changes in the developing nervous system, should neonatal pain be inadequately managed (Simons *et al.,* 2003; Parry, 2008). This is concerning, especially in light of the statement by Ranger *et al.* (2007) that crying, especially in fragile newborns, can be detrimental to their health due to the increased intracranial pressure, as well as the high energy consumption.

This debate is well summarised in the statement made by Derbyshire (2008): “There is now enough evidence that clinical benefits outweigh risks from anaesthetic or analgesic intervention during procedures on neonates and infants, regardless of whether evidence supports or denies neonatal pain”.

Parry (2008) concluded in a study that “the purpose of pain management is to resolve or reduce pain whilst minimizing the side effects of treatments”. Shah and Suresh (2013) advocate that the scope of paediatric pain management has significantly improved due to the increased use of regional anaesthesia in the paediatric population. They also accentuate that the literature supports the safety and efficacy of the use of regional anaesthesia on this specific group of patients. Berde and co-workers (2005) mentioned that, due to the use of opioids and other agents, and management of adverse effects there-of, more local anaesthetics are being used in infants and neonates.

Rochette *et al.* (2009) compared two studies by the French language paediatric anaesthetists society (Association des Anesthésistes Réanimateurs Pédiatriques d'Expression Française: ADARPEF). The first study was conducted in 1994, while the second was a prospective survey over a period of one year between 2005 and 2006. The most significant difference observed between these two studies is the 200 – 500% increase in the performance of peripheral nerve blocks.

One factor that can explain the increased performance of peripheral nerve blocks is captured in a statement by Lyon (2005), in which he mentions that general anaesthesia should only be administered to infants after four months of age, due to the immaturity of their haemoglobin.

Another factor in the consideration of regional anaesthesia in paediatric patients, is safety. In a large multicentre prospective study conducted by Giaufre and co-workers (1996), more than 24 000 nerve block procedures in paediatric patients were evaluated. Only 23 adverse reactions, with no long-lasting side effects, were observed.

Ivani and De Negri (2001) list the following factors for the increased use of regional anaesthesia in paediatric patients:

- Realisation and awareness of experienced pain and the use of analgesics;
- Evidence on the efficacy of regional anaesthesia;
- Increased information being made readily available;
- Safety of the use of regional anaesthesia in a population group.

Dalens (2006) makes the following statement: "With sound judgment and appropriate scientific knowledge, regional anaesthesia represents in many instances the best technique to provide adequate intraoperative and postoperative pain relief in paediatric patients."

1.1.2 History synopsis of regional anaesthesia in paediatric patients

The use of paediatric regional anaesthesia can be traced back several millennia, with a carved Egyptian low relief of Saqqarah indicating the possible 'Stone of Memphis' being used during a circumcision (Dalens, 1989). These practices were relinquished by later civilisations. For a short period between the end of the 19th and beginning of the 20th century, spinal~, as well as supraclavicular nerve~ and brachial plexus blocks were being performed (Bier, 1899; Bainbridge, 1901; Gray, 1909, Dalens, 1989). August Bier (1899) described the first successful use of spinal anaesthesia in surgery of a thigh tumour in an 11-year old patient. However, due to several reasons, including the advances in general anaesthesia and the development of safer agents, these techniques were discontinued (Dalens, 1989).

In 1933, Meredith Campbell presented a paper to the American Society of Regional Anaesthesia in which she explained how she used caudal blocks for cystoscopies in children. Previously, patients received morphine and phenobarbitone premedication and, either novocaine implanted into their urethra, or were placed under general anaesthesia (Campbell, 1933; Brown, 2012).

A renewed interest in paediatric regional anaesthesia was experienced in the 1970's through reports by Lourey and McDonald (1973), Kay (1974), Melman *et al* (1975), as well as Carpenter (1976), as reported by Dalens (1989).

From chewing coca leaves to alleviate toothache in the 1500's, to the first use of cocaine in eye surgery by Viennese ophthalmologist Koller in 1884 (Walsh and Walsh, 2011), to the direct visualisation of the brachial plexus as it is dosed with cocaine in the 1980's (Winnie, 1983; Denny and Harrop-Griffiths, 2005), the use of regional anaesthesia has advanced drastically. Due to greater advances, an increased use, even in the paediatric population, has been observed (Dalens, 1989; Giaufre *et al.,* 1996).

For head and neck procedures in children, regional anaesthesia can provide great benefits such as increased pain control, easier recovery and even, in certain cases, same-day discharge (Belvis *et al.,* 2007). Suresh and Voronov (2012) even claim that more children are receiving head and neck blocks than adults. Jöhr (2000) makes the following statement: "The routine perioperative use of local or regional anaesthesia in all children, unless there is a specific contraindication, is the foundation of effective postoperative analgesia".

1.1.3 Clinical implication of regional anaesthesia in paediatric patients

In 1987, Anand and Hickey made this final statement in their study on neonatal pain and its effects: "Like persons caring for patients of other ages, those caring for neonates must evaluate the risks and benefits of using analgesic and anaesthetic techniques in individual patients. However, in decisions about the use of these techniques, current knowledge suggests that humane considerations should apply as forcefully to the care of neonates and young, nonverbal infants as they do to children and adults in similar painful and stressful situations."

A very important statement was made by Denny and Harrop-Griffiths (2005): “Regional anaesthesia always works – provided you put the right dose of the right drug in the right place”. Giaufré and co-workers (1996) also state that, with simple guidelines for the use of regional nerve blocks, high quality analgesia can be achieved in paediatric patients. However, adequate anatomical research is required in order to accurately and successfully utilise this valuable and safe tool.

Berde et al. (2005) discuss several technical challenges with the administration of regional anaesthesia to neonates and infants, which include the ability of adult patients to report on paraesthesia, numbness and analgesia due to the anaesthetic being administered while being awake. Paediatric patients, however, receive regional anaesthesia while being anaesthetised, which is referred to as ‘double anaesthesia’ by Ivani and De Negri (2001). This results in the inability of the patient to comment on sensory changes during needle~ and catheter placement (Berde et al., 2005).

In accordance with the above statement, unlike regional anaesthesia in adult patients, regional anaesthesia in infants and children is predominantly performed with the patient placed under deep sedation or general anaesthesia (Shah and Suresh, 2013). The practising anaesthetist, therefore, should be able to successfully perform the regional anaesthetic procedure without relying on signals from the patient (Dalens, 1989).

Paediatric patients undergo a variety of surgical procedures in the head and neck region. Several peripheral nerve blocks have been introduced to provide adequate intraoperative and postoperative pain control (Suresh and Voronov, 2006; Voronov and Suresh, 2008). However, with regard to the use of regional anaesthesia in neonates, opinions are still divided, not because of the efficacy of the regional anaesthesia, but due to the safety of performing regional anaesthesia in newborns (Jöhr and Berger, 2004). “The choice of block is ultimately dependant on the skill of the practitioner and the safety of the baby”. This statement was made by Adrian Bosenberg in a pro-con debate with regard to the use of regional and systemic analgesia in neonatal surgery (Bosenberg *et al.,* 2011).

The following very important statement was made by Schendel and co-workers (2005): "Competency requires the appropriate decision making based on knowledge of anatomy, pathology and surgical technique combined with technical proficiency. Technical proficiency is comprised of efficient time motion, tissue handling, knowledge of procedure, visual spatial ability and dexterity".

1.1.4 Importance of anatomical knowledge in regional anaesthesia in paediatric patients

One of the quandaries of clinical anatomy with regard to paediatric practice is that anatomy, for the most part, is based on studies performed in adults. This is then extrapolated to infants and children, which in many cases may be erroneous. Clinical anatomy of the head and neck, for example, changes as the bones of the skull develop and the child grows.

According to the American Association of Clinical Anatomists (1999), anaesthesiologists play a critical role in head and neck surgeries. Their role is not limited to providing anaesthesia during surgical procedures, since they are also involved in the preparation of surgical patients and the relief of postoperative pain. The expertise that anaesthesiologists display during these procedures, especially when employing regional nerve blocks, depends on a thorough knowledge of the relevant anatomy specific for the procedure. Clinical procedures that fail to achieve their objective, or that result in complications, can often be linked to a lack of understanding, or misunderstanding, of the relevant anatomy.

Various authors (Abrahams and Webb, 1975; McMinn *et al*., 1984; Beahrs *et al*., 1986; Crisp, 1989; Ger and Evans, 1993; American Association of Clinical Anatomists, 1999; Boon *et al*, 2004a and b; van Schoor et al., 2005; van Schoor et al., 2013; Prigge et al., 2014) have emphasised the important role of sound anatomical knowledge to ensure the safe and successful performance of a clinical procedure. This also provides the primary basis for the successful, safe and competent performance of invasive procedures.

Regional anaesthesia is becoming increasingly popular in paediatric anaesthesia practice. The question regarding the importance of clinical anatomy is often raised. Since the development of regional anaesthesia in 1884, through the second half of the 20th century, regional anaesthesia was practiced as an art, where the knowledge of anatomy was of utmost importance (Franco, 2008). This is especially true when regional anaesthesia is practiced in children. Ivani states: “It has been recognised that infants and small children are not really small adults, and that we cannot apply adult standards to the care of paediatric patients” (Ferrari, 1999; Ivani and Negri, 2001). Infants cannot be considered as anatomical miniatures of adults (Morris, 1998; Avidan *et al.,* 2003). A thorough understanding of the anatomical differences between children, especially neonates, and adults is essential.

Safe nerve blockade (in particular) requires precise knowledge of the course, position and depths of the target nerve in order to ensure that the needle tip is placed close enough to anaesthetise, but not damage the nerve (Doyle, 2007; Captier *et al.*, 2009). Therefore, the key to a successful regional anaesthetic nerve block is the awareness and expertise of the practitioner. Knowledge on the position of the nerve and its relationship to bony landmarks is an added advantage (Salam, 2004). Consequently, to perform and evaluate these nerve blocks in children, the relevant anatomy needs to be studied, since, in many instances, only adult data is available.

Even though paediatric regional anaesthesia is being practiced more regularly with success and safety, a “gap” remains in our knowledge regarding the exact anatomy concerned with paediatric nerve blocks (Berde *et al.,* 2005). This research will concentrate on the underlying clinical anatomy necessary to perform a safe and successful procedure and to provide a better understanding of advanced ultrasound imaging.

1.1.5 Paediatric anaesthesia in Africa

"Adequate management of patients requires fine-tuning of available techniques. Pain management is no exception, as it mainly aims at improving the comfort of the patient" (Dalens, 2006). This is a very important statement. However, the feasibility of regional anaesthesia in the developing world needs to be evaluated.

Bosenberg (2007) published a paper on paediatric anaesthesia in developing countries and states that countries are classified by economists according to either national income, or on the Human Development Index, which ranks the average human development of each specific country based on life expectancy, literacy and the measures of health and quality of life (Kumar and Tynan, 2005; Bosenberg, 2007). Seventy percent of the world's poorest countries are in sub-Saharan Africa. "Although we as anaesthesiologists would prefer otherwise, anaesthesia services, let alone paediatric anaesthesia, are not considered a major healthcare issue" (Bosenberg, 2007).

In a systematic review conducted by Ekenze and co-workers (2015) on neonatal surgery in Africa, the following major challenges were identified:

- Delayed presentation and inadequate facilities in 76.5% of evaluated studies;
- Shortage of trained support personnel in 62.7% of assessed studies;
- Absence of neonatal intensive care in 56.9% of observed studies.

In conjunction with the abovementioned observations, the following factors, compiled from different sources, are mentioned by Bosenberg (2007) with regard to anaesthesia:

- Facilities such as providing adequate analgesia, recovery area, as well as ventilatory support, is either inadequate or absent;
- Erratic electricity supply makes equipment such as syringe pumps and other control devices unfeasible;
- General commodities such as endotracheal tubes are often unavailable and lead to the re-use of several disposable equipment;

- Most anaesthetics are performed by non-physicians, nurses and unqualified personnel, who are “trained on the job”.

The above listed factors are but a few that trouble the developing world. Yet, Bosenberg (2007) states: “Regional anaesthesia may provide the solution to some of these problems and may be the only choice in some situations”.

Regional anaesthesia is preferred since analgesia can be extended into the postoperative period (Ivani and Negri, 2001), with fewer complications compared to opioids and non-steroidal anti-inflammatories (Jonnavithula, 2010). The main advantage of regional anaesthesia is the ability to selectively anaesthetise a specific region of the body, with little or no effect on other areas such as the brain, lungs and heart. All the patient’s protective reflexes remain intact, with the patient being fully conscious but without discomfort or pain (Mayo Clinic, 2006). This may be particularly important to doctors working with limited resources in developing countries or to volunteers of charity medical organisations such as Doctors Without Borders and Operation Smile.

In the conclusion on the study by Bosenberg (2007), he states: “Unfortunately with all the goodwill in the world there is no guarantee that money will ever reach the right people and be put to the best use. Purchasing equipment without subsequent maintenance is wasteful. Disposables are short-lived even if they are recycled. Human resources are needed!”

Skills need to be developed, with regard to the performance of paediatric regional anaesthesia in order to facilitate the circumstances in the developing world. Bosenberg (2014) emphasises that it is not the agents that are used that determine the outcome of a nerve block, but the skill with which the agent is delivered to the target nerve. However, due to a lack of education, fear of failure or a lack of necessities, regional anaesthesia is not readily performed in children.

Statements such as the following, emphasise the need for anatomical research in conjunction with the development of skills: “Unfortunately, anatomy is not exactly predictable and the natural variability of human anatomy led to poor success rates for many peripheral nerve blocks. Much of the antipathy towards regional anaesthesia has its origins in those arguably ‘hit and miss’ times. Part of this may have been a lack of understanding of the anatomy” (Marhofer *et al.,* 2010).

Marhofer and colleagues (2005) mention in a paper on ultrasound and regional anaesthesia that it is not the needle that anaesthetises the nerve, but the local anaesthetic. Yet, the local anaesthetic needs to be accurately delivered to the targeted nerve. Willschke *et al.* (2010) state that peripheral nerve blocks, especially in young children, are considered challenging based on the poorly defined surface landmarks, as well as the challenges of determining the exact location of the nerves in growing children, due to variable depths and positions. Thus, landmark-based anatomical studies will assist with the challenges often experienced.

“In paediatrics, regional techniques are usually performed for improving the comfort of the patient, even though not absolutely necessary for the completion of the operation. Therefore, the techniques must not be potentially detrimental to the patients. To ensure safety, it is important to use precise techniques for ascertaining the position of the tip of the needle as well as for injecting the anaesthetic solution” (Dalens, 1989).

With the aforementioned statement in mind, a survey was conducted amongst clinicians in South-Africa by Prigge and co-workers (2013). Five “problem” regional anaesthetic procedures in the head and neck region were identified. These procedures were identified as being performed, but under-utilised because of lack of confidence or anatomical knowledge of anaesthesiologists to perform these blocks on children.

The nerve blocks identified were (1) the maxillary nerve block (extra-oral approach), (2) supraorbital and supratrochlear nerve block, (3) infraorbital nerve block (extra-oral approach) (4) superior laryngeal nerve block and (5) recurrent laryngeal nerve block. However, after an additional review of the available literature, re-evaluation of results obtained in the study by Prigge *et al.* (2013), as well as in communications with a senior consultant paediatric anaesthesiologist, the latter two nerve blocks were replaced with the greater occipital and superficial cervical plexus nerve blocks. This decision is based on the frequency of performance, anatomy related complications and difficulties experienced, as well as the clinical importance of these nerve blocks. The advantage of an informative anatomical study based on the greater occipital nerve block, as well as the superficial cervical nerve block would greatly assist practising paediatric anaesthesiologists in providing adequate anaesthesia and analgesia of the anterior neck and scalp.

The purpose of this descriptive anatomical study is to extensively examine the anatomy of each of these nerve blocks on a relevant sample of cadaveric and osteological specimens.

1.2 Overall aims of this research study

The aim of this study is threefold. Firstly, to aid anaesthesiologists in the performance of nerve blocks in the head and neck region in infants and children through thorough investigation, and where relevant, correct misconceptions relevant to each procedure. Secondly, to increase the confidence of practicing anaesthesiologists to perform these procedures in infants and children, and thirdly, to minimise complications related to these procedures by providing an extensive anatomical description pertaining to each procedure.

1.3 Overall materials and methods applicable to this research study

1.3.1 Choice of research and subject

A descriptive anatomical research study was conducted on both neonatal and infant osteological and cadaveric specimens.

1.3.2 Type of study

A quantitative research method obtained through an observation and practically applied study design.

1.3.3 Collection of data

All osteological assessments and cadaveric dissections were performed within the Department of Anatomy, Basic Medical Sciences building, Prinshof Campus of the University of Pretoria.

Fifty formalin-fixed paediatric specimens (or cadavers) were obtained for the anatomical dissections. These specimens were selected based on no observed cranial or facial deformities, in order to ensure that no dissection or data collection would be hindered.

All cadaveric dissections were performed using a standard micro-dissection kit. Once dissections were completed, high-quality digital photographs were taken and imported into an image software program (Image Tool V3.0) to assist with the calculation of the measurements. On-site measurements were taken with a Vernier digital calliper (accuracy of 0.01mm). All measurements obtained were entered into the Excel® data sheet, while statistical analyses were performed using the statistical program SAS® version 9.3, for Windows.

1.3.4 Ethical considerations and logistics

In order to achieve the aims of this research study, ethical approval was obtained from the Faculty of Health Sciences Research Ethics Committee of the University of Pretoria (Appendix A). All neonatal cadavers used in this study were acquired and dissected under the rules and regulations defined within the South African Health Act (Act 61 of 2003). These cadaveric specimens form part of the cadaver collection of the Department of Anatomy, University of Pretoria. All cadavers were obtained through donation by the family members, or due to the deceased being unclaimed by family members. The material was handled with respect and care at all times and was properly safeguarded. No information which could possibly reveal the identities of the cadavers was obtained.

1.3.5 Statistical analysis and comparisons

All statistical analyses and comparisons were conducted by statistician Dr L Louw and research consultant Mrs J Jordaan at the Department of Statistics, University of Pretoria, using the statistical program SAS® version 9.3, for Windows.

In order to ensure that accurate results were obtained, intra-rater reliability and inter-rater reliability were measured. The primary investigator repeated 25% of the measurements, while an independent researcher duplicated 12.5% of the measurements. The two sets of data were compared by using both Student T-tests and intraclass correlation coefficients to ensure that the initially acquired measurements were statistically correct. A p-value of smaller or equal to 0.05 was regarded as a statistically significant difference between the two data sets.

1.4 Overall results applicable to this research study

In order to determine the validity and accuracy of the obtained measurements, intra-observer and inter-observer checks were conducted. The primary investigator repeated 25% of the initial measurements, while an independent researcher duplicated 12.5% of the measurements. The two data sets where compared to ensure that the measurements were valid. The statistical results for these comparisons are presented in Table 1.1.

Table 1.1: Results of statistical analysis for intra- and inter-rater reliability

	Intra-rater reliability	**Inter-rater reliability**
Student T-test	p = 0.6210	p = 0.7263
Intraclass correlation coefficient	0.981	0.986

With regard to intra-rater reliability, the p-value for the Student T-test was 0.6210, while the intraclass correlation coefficient was measured at 0.981. A p-value of 0.7263 was obtained with the Student T-test for inter-rater reliability, while the intraclass correlation coefficient was found to be 0.986. Therefore, the initially obtained data measurements are considered correct.

A Student T-test is used to determine whether the means of the measurements obtained in two data sets are statistically different from each other (McDonald, 2014). For both the intra-rater reliability and the inter-rater reliability, a p-value greater than 0.05 was obtained, as seen in Table 1.1. Therefore, no statistically significant difference was noticed between the first and second sets of obtained measurements, based on the Student T-test.

The authors of the manual for MedCalc statistical software (2016) define the intraclass correlation coefficient (ICC) as a measure of the reliability of two or more sets of measurements. As seen in Table 1.1, the paired ratings are in perfect agreement with an ICC of 0.981 and 0.986 for intra-rater and inter-rater reliability, respectively.

According to the results of the Student T-test and the intraclass correlation coefficient, there is an absolute agreement between the two raters. Therefore, the originally obtained data set is considered accurate and statistically correct.

Results of each individual nerve block are presented in Chapters 2 – 5, with each block described on its own, in article format.

1.5 References

Abrahams, PH; Webb, P. (1975) Clinical anatomy of practical procedures. London: Pitman Medical. p 55 – 59

American Association of Clinical Anatomists. (1999) Educational affairs committee. The clinical anatomy of several invasive procedures. *Clin Anat* 12: 43 – 54

Anand, KJS; Hickey, PR. (1987) Pain and its effects in the human neonate and fetus. *N Engl J Med* 317 (21): 1321 – 1329

Avidan, M; Harvey, AMR; Ponte, J; Wendon, J; Ginsburg, R. (2003) Perioperative care, anaesthesia, pain management and intensive care. An illustrated colour text. Churchill Livingstone. Elsevier Science Limited

Bainbridge, WS. (1901) A report of twelve operations on infants and young children during spinal anesthesia. *Arch Pediatr* 18:570 – 574

Beahrs, OH; Chase, RA; Ger, R. (1986) Gross anatomy in medical education. *Am Surg* 2: 227 – 232

Belvis, D; Voronov, P; Suresh, S. (2007) Head and neck blocks in children. *Tech Reg Anesth Pain Manag*. 11: 208 – 214

Berde, CB; Jaksic, T; Lynn, AM; Maxwell, LG; Soriano, SG; Tibboel, D. (2005) Anesthesia and analgesia during and after surgery in neonates. *Clin Ther* 27: 900 – 921

Bier, A. (1899) Experiment regarding the cocainization of the spinal cord. *Zentralbl Chir* 51: 361 – 369

Boon, JM; Abrahams, PH; Meiring, JH; Welch, T. (2004a) Cricothyroidotomy: A clinical anatomy review. *Clin Anat* 17:478 – 486

Boon, JM; Abrahams, PH; Meiring, JH; Welch, T. (2004b) Lumbar puncture: anatomical review of clinical skill. *Clin Anat* 17: 544 – 553

Bosenberg, AT. (2007) Pediatric anesthesia in developing countries. *Curr Opin Anesthesiol* 20: 204 – 210

Bosenberg, AT. (2014) Neonatal anesthesia with limited resources. *Ped Anesth* 24: 98 – 105

Bosenberg, AT; Jöhr, M; Wolf, AR. (2011) Pro con debate: the use of regional vs systemic analgesia for neonatal surgery. *Ped Anesth* 21: 1247 – 1258

Brown, TCK. (2012) History of pediatric regional anesthesia. *Ped Anesth* 22: 3 – 9

Captier, G; Dadure, C; Leboucq, N; Sagintaah, M; Canaud, N. (2009) Anatomic study using three-dimensional computed tomographic scan measurement for truncal maxillary nerve blocks via the suprazygomatic route in infants. *J Craniofac Surg* 20: 224 – 228

Campbell, MF. (1933) Caudal anesthesia in children. *American J Urol* 30: 245 – 249

Carpenter, MB. (1976) Development and histogenesis of the nervous system. In: Carpenter MB, ed Human Neuroanatomy 7th edition. p 49 – 70

Dalens, B. (1989) Regional anesthesia in children: review article. *Anesth Analg* 68: 654 – 672

Dalens, B. (2006) Some current controversies in paediatric regional anaesthesia. *Curr Opin Anesthesiol* 19: 301 – 308

Denny, NM; Harrop-Griffiths, W. (2005) Editorial I: Location, location, location! Ultrasound imaging in regional anaesthesia. *Br J Anaesth* 94 (1): 1 – 3

Derbyshire, SWG. (2008) Fetal pain: do we know enough to do the right thing? *Reprod Health Matters* 16 (31 Suppl): 117 – 126

Doyle, E. (2007) Paediatric anaesthesia: Oxford specialist handbooks in anaesthesia. Edited by Edward Doyle. Oxford University Press. p 4

Ekenze, SO; Ajuzieogu, OV; Nwomeh, BC. (2015) Neonatal surgery in Africa: a systematic review and meta-analysis of challenges of management and outcome. Published online 27 April 2015 www.thelancet.com Surgical outcomes (abstract) p 35

Ferrari, LR. (1999) Anesthesia and Pain management for the paediatrician. The Johns Hopkins University Press. Baltimore & London

Franco, CD. (2008) Regional anesthesia and the role of anatomy today. *Tech Reg Anesth Pain Manag* 12: 125 – 126

Ger, R; Evans, JT. (1993) Tracheostomy: an anatomico-clinical review. *Clin Anat* 6: 337 – 341

Giaufré, E; Dalens, B; Gombert, A. (1996) Epidemiology and morbidity of regional anesthesia in children: a one-year prospective survey of the french-language society of pediatric anaesthesiologists. *Anesth Analg* 83: 904 – 912

Gray, HT. (1909) A study of subarachnoid block in children and infants. *Lancet* 2: 913 – 917

Grunau, RE; Holsti, L; Peters, JWB. (2006) Long-term consequences of pain in human neonates. *Semin Fetal Neonatal Med* 11: 268 – 275

Ivani, G; Negri, PD. (2001) New insight into paediatric regional anaesthesia: new drugs. *Curr Opin Anaesth*. Jun 14: 353 – 357

Jöhr, M. (2000) Postoperative pain management in infants and children: new developments. *Curr Opin Anaesth* 13(3): 285 – 289

Jöhr, M; Berger, TM. (2004) Regional anesthetic techniques for neonatal surgery: indications and selection of techniques. *Best Pract Res Clin Anaesthesiol* 18: 357 – 375

Jonnavithula, N; Durga, P, Kulkarni, DK; Ramachandran, G. (2007) Bilateral intra-oral, infra-orbital nerve block for postoperative analgesia following cleft lip repair in paediatric patients: comparison of bupivacaine vs. bupivacaine-pethidine combination. *Anaesthesia* 62: 581 – 585

Kay, B. (1974) Caudal blocks for postoperative pain relief in children. *Anaesthesia* 29: 610 – 611

Kumar, RK; Tynan, MJ. (2005) Catheter interventions for congenital heart disease in third world countries. *Pediatr Cardiol* 26: 241 – 249

Lourey, CJ; McDonald, IM. (1973) Caudal anaesthesia in infants and children. *Anaesth Int Care* 1: 547 – 548

Lyon, VB. (2005) Appoach to procedures in neonates. Dermatol Ther 18: 117 – 123

Marhofer, P; Greher, M; Kapral, S. (2005) Ultrasound guidance in regional anaesthesia. *Br J Anaesth* 94: 7 – 17

Mayo Clinic. (2006) Anesthesia: a look at local, regional and general anesthesia. Cited from www.cnn.com/HEALTH/Library/SC/00026.html on 10 Feb 2010

McDonald, JH. (2014) Handbook of biological statistics (3rd edition) Sparky house publishing, Baltimore, Maryland, p 126 – 130

McMinn, RMH; Hutchings, RT; Logan, BM. (1984) A colour atlas of applied anatomy. London: Wolfe Medical Publications

MedCalc. (2016) Complete statistical program for windows. Information obtained 18-7-2016 from https://medcalc.org/manual/intraclasscorrelation.php

Melman, E; Penuelas, J; Marrufo, J. (1975) Regional anesthesia in children. *Anesth Analg* 54: 387 – 390

Morris, SE. (1998) Issues in the anatomy and physiology of swallowing: impact on the assessment and treatment of children with dysphagia. Cited from http://www.new-vis.com/fym/papers/p-feed10.htm on 22 Sept 2011

Parry, S. (2008) Acute pain management in the neonate. *Anaesth Intensive Care Med* 9(4): 147 – 151

Prigge, L; Van Schoor, A-N; Bosman, MC. (2013) Evaluation of paediatric regional anaesthetic procedures in the head and neck region. MSc dissertation. University of Pretoria

Prigge, L; van Schoor, A-N; Bosman, MC; Bosenberg, AT. (2014) Clinical anatomy of the maxillary nerve block in pediatric patients. *Ped Anesth* 2014; 24:1120 – 1126

Ranger, M; Johnston, C; Anand, KJS. (2007) Current controversies regarding pain assessment in neonates. *Semin Perinatol* 31: 283 – 288

Rochettem, A; Dadure, C; Raux, O; Capdevila, X. (2009) Changing trends in paediatric regional anaesthetic practice in recent years. *Curr Opin Anesthesiol* 22: 374 – 377

Salam, GA. (2004) Regional anesthesia for office procedures: Part I. Head and neck surgeries. *Am Fam Physician* 69: 585 – 590

Schendel, S; Montgomery, K; Sorokin, A; Lionetti, G. (2005) A surgical simulator for planning and performing repair of cleft lips. *J Craniomaxillofac Surg* 33: 223 – 228

Shan, RD; Suresh, S. (2013) Applications of regional anaesthesia in paediatrics. *Br J Anaesth* 111(S1): i114 – i124

Simons, SH; van Dijk, M; Anand, KS; Roofthooft, D; van Lingen, RA; Tibboel, D. (2003) Do we still hurt newborn babies?: A prospective study of procedural pain and analgesia in neonates. *Arch Pediatr Adolesc Med* 157(11): 1058 – 1064

Suresh, S; Voronov, P. (2006) Review article. Head and neck blocks in children: an anatomical and procedural review. *Ped Anesth* 16: 910 – 918

Suresh, S; Voronov, P. (2012) Review article. Head and neck blocks in infants, children, and adolescents. *Ped Anesth* 22: 81 – 87

Taddio, A; Goldback, M; Ipp, M; Stevens, B; Koren, G. (1995) Effect of neonatal circumcision on pain responses during vaccination in boys. *Lancet* 345: 291 – 292

Taddio, A; Katz, J; Ilersich, AL; Koren, G. (1997) Effect of neonatal circumcision on pain response during subsequent routine vaccination. *Lancet* 349: 599 – 603

Van Schoor, A-N; Boon, JM; Bosenberg, AT; Abrahams, PH; Meiring, JH. (2005) Anatomical considerations of the paediatric ilio-inguinal/ iliohypogastric nerve block. *Ped Anesth* 15: 371 – 377

Van Schoor, A-N; Bosman, MC; Bosenberg, AT. (2013) Revisiting the anatomy of the ilio-inguinal / iliohypogastric nerve block. *Ped Anesth* 23: 390 – 394

Voronov, P; Suresh, S. (2008) Head and neck blocks in children. *Curr Opin Anaesth* 21: 317 – 322

Walsh, A; Walsh, S. (2011) Local anaesthesia and the dermatologist. *Clin Exp Dermatol* 36: 337 – 343

Willschke, H; Marhofer, P; Machata, AM; Lonnqvist, PA. (2010) Current trends in paediatric regional anaesthesia. *Anaesthesia* 65 (Suppl1): 97 – 104

Winnie, AP. (1983) Historical considerations. In: Plexus Anesthesia, perivascular techniques of the brachial plexus. Philadelphia: W. B Saunders. p 68 – 69

2 Maxillary nerve block

As part of the pilot study for this PhD thesis, the maxillary nerve block was evaluated on cadaveric and osteological specimens. The best method to block the maxillary nerve block in paediatric patients was developed.

Below is the article based on the pilot study, as published in the Pediatric Anesthesia journal in 2014. Certain aspects from this article have been adapted and modified, in line with the remainder of this thesis. However, the complete article as published can be obtained from https://www.ncbi.nlm.nih.gov/pubmed/25040918.

Clinical anatomy of the maxillary nerve block in paediatric patients

Lané Prigge, Albert-Neels van Schoor, Marius C. Bosman, Adrian T. Bosenberg

Pediatric Anesthesia 2014; 24: 1120 – 1126

2.1 Introduction

Cleft lip and/or palate are considered to be the most frequently encountered craniofacial malformation (Haberg *et al.,* 1998)**,** with a worldwide incidence of approximately 1 in 1000 live births (Thaller *et al.,* 1995; Strong and Buckmiller, 2001; Moore *et al.,* 2011). Congenital cleft palate repair is ideally performed in the first year of life. The surgery is also considered to be an extremely painful procedure, with the most significant pain experienced in the early postoperative period (Doyle and Hudson, 1992; Obayah *et al.,* 2010).

Regional anaesthesia has a number of advantages and can provide postoperative analgesia in infants and neonates, without the risk of respiratory depression (Welborn *et al.,* 1986). Maxillary nerve block within the pterygopalatine fossa can provide sensory blockade of the hard and soft palate (Rochette *et al.,* 2009) and, in this way, provide intraoperative and postoperative analgesia. For the best results, the maxillary nerve needs to be blocked prior to the division of the greater palatine nerve at the location of the foramen rotundum or within the pterygopalatine fossa. The nerve is shielded by the anterior border of the lateral pterygoid plate, superiorly and laterally, as it exits from this foramen (Singh *et al.,* 2001). The optimal location for a maxillary nerve block is therefore within the pterygopalatine fossa.

A maxillary nerve block can be considered efficient, simple and safe and improves patient comfort and postoperative analgesia according to Mesnil and co-workers (Mesnil *et al.,* 2010). Although several techniques to block the maxillary nerve have been described (Stechison and Brogan, 1994; Du Plessis, 2010; Mesnil *et al.,* 2010), this is the first study to evaluate this block in paediatric cadavers, according to the authors.

2.2 Aims

This study evaluates the anatomy of three different approaches to the maxillary nerve block in neonatal and infant cadavers with the aim of establishing the most effective method of blocking the maxillary nerve within the pterygopalatine fossa in this age group.

2.3 Materials and Methods

Three approaches to the maxillary nerve block were chosen based on a review of the literature. The following criteria were used to select the three techniques:

- Newly developed (technique A, has not been evaluated yet);
- Most commonly performed (technique B is the most described method in the literature);
- Easily comparable (technique C is performed in the same plane and therefore easy to compare to technique A and B).

These techniques were then simulated on 10 dried paediatric skulls and 30 formalin fixed dissected paediatric cadavers within the Department of Anatomy, University of Pretoria, South Africa and conducted according to the Declaration of Helsinki. All cadavers and skulls were legally obtained (according to the South African National Health Act, Act 61 of 2003) and stored in the Department of Anatomy for research and teaching purposes. Ethical clearance to perform this study on the sample of neonatal cadavers was obtained from the Faculty of Health Sciences Research Ethics Committee of the University of Pretoria.

Needles were inserted into the pterygopalatine fossa using the guidelines set out for the three techniques (as described in the paragraphs prior to Figure 2, 3 and 4 respectively). Two of the techniques were suprazygomatic approaches (technique A and technique B) while technique C was an infrazygomatic approach. The sample was divided into two age groups: Group 1 consisted of skulls and cadavers of neonates (0 – 28 days after birth) and Group 2 consisted of the infant skulls and cadavers from 28 days to one year of age. Seven neonatal skulls and 25 neonatal cadavers were measured in Group 1, while three paediatric skulls and five cadavers were measured in Group 2. All three techniques were simulated on both sides of each skull and cadaver. High quality digital photographs were then taken from a superior, anterior and lateral view and subsequently imported into an image analysis program called UTHSCSA Image Tool Version 3. The needle depth and angles to enter the pterygopalatine fossa were then measured and tabulated. The depth was measured from the zygomatic process of the maxillary bone.

From an anterior view, the plane perpendicular to the median plane was considered to be 0°. If the needle is angled superiorly towards the pterygopalatine fossa, it will be considered as an increase (+) in the angle while any inferior angling of the needle will be a decrease (-) (Figure 2.1A). From a superior view, the perpendicular plane was again considered to be 0° with any anterior deviation seen as an increase (+) and any posterior deviation as a decrease (-) in the angle (Figure 2.1B).

Figure 2.1: (A) Anterior view and (B) superior views of the paediatric skull indicating the superior / inferior and anterior / posterior angles of the needle, respectively

All measurements for the left and right sides (left *vs.* right) and the dry skulls and cadavers (skulls *vs.* cadavers) were compared. The skull measurements were seen as the "ideal" values based on the "visibility" of the pterygopalatine fossa and ease of needle insertion. In contrast, the cadaver measurements were considered to be the "real" values as they more accurately simulated the clinical setting. A technique was considered to be effective if no difference existed between the cadaver ("real") and skull ("ideal") measurements.

In technique A (Figure 2.2A & Figure 2.2B) the needle was placed adjacent to the lateral orbital wall at the midpoint of the orbital opening. The needle was advanced in an inferior direction to reach the pterygopalatine fossa (Du Plessis, 2010).

Figure 2.2: Technique A simulated on (A) a paediatric skull and (B) cadaver

In technique B (Figure 2.3A & Figure 2.3B), the needle was placed at the frontozygomatic angle and then advanced medially until the pterygopalatine fossa was reached (Mesnil *et al.,* 2010).

Figure 2.3: Technique B simulated on (A) a paediatric skull and (B) cadaver

In technique C (Figure 2.4A & Figure 2.4B) the needle was inserted through the cheek at a point where a vertical line, extending along the lateral orbital wall, intersected with a horizontal line that ran perpendicular to the lateral aspect of the inferior surface of the zygomatic process of the maxilla (Stechison and Brogan, 1994).

Figure 2.4: Technique C simulated on (A) a paediatric skull and (B) cadaver

2.4 Results

No statistically significant differences ($p > 0.05$; paired T-test) were found between the left and right sides of either the skulls or the cadavers for all three techniques. The sample size for each technique was therefore doubled by the combination of the results, as seen in Table 2.1.

Table 2.1: Overall results obtained for paediatric skulls and cadavers, for Group 1 and 2.

	Measurements of pediatric skulls																	
	Age group 1									***Age group 2***								
	Technique A			**Technique B**			**Technique C**			**Technique A**			**Technique B**			**Technique C**		
	Sup – Inf (°)	**Ant – Post (°)**	**Depth (mm)**	**Sup – Inf (°)**	**Ant – Post (°)**	**Depth (mm)**	**Sup – Inf (°)**	**Ant – Post (°)**	**Depth (mm)**	**Sup – Inf (°)**	**Ant – Post (°)**	**Depth (mm)**	**Sup – Inf (°)**	**Ant – Post (°)**	**Depth (mm)**	**Sup – Inf (°)**	**Ant – Post (°)**	**Depth (mm)**
n	14	14	14	14	14	14	14	14	14	6	6	6	6	6	6	6	6	6
Mean	13.80	16.20	24.40	0.73	13.21	22.34	-26.80	24.25	21.42	13.93	12.43	32.73	-3.25	9.06	31.48	-28.72	23.37	34.77
SD	6.33	8.50	6.11	4.83	7.74	7.04	9.05	7.99	6.70	2.28	5.48	6.14	2.38	6.15	6.48	4.62	5.20	3.66
CI95%	3.31	4.45	3.20	2.53	4.06	3.69	4.74	4.18	3.51	1.82	4.38	4.91	1.90	4.92	5.18	3.70	4.16	2.93
Lower	10.48	11.74	21.20	-1.80	9.16	18.65	-31.54	20.06	17.91	12.11	8.05	27.82	-5.15	4.14	26.29	-32.42	19.21	31.84
Upper	17.11	20.65	27.60	3.26	17.27	26.02	-22.06	28.43	24.93	15.76	16.82	37.64	-1.35	13.98	36.66	-25.02	27.53	37.70

	Measurements of pediatric cadavers																	
	Age group 1									***Age group 2***								
	Technique A			**Technique B**			**Technique C**			**Technique A**			**Technique B**			**Technique C**		
	Sup – Inf (°)	**Ant – Post (°)**	**Depth (mm)**	**Sup – Inf (°)**	**Ant – Post (°)**	**Depth (mm)**	**Sup – Inf (°)**	**Ant – Post (°)**	**Depth (mm)**	**Sup – Inf (°)**	**Ant – Post (°)**	**Depth (mm)**	**Sup – Inf (°)**	**Ant – Post (°)**	**Depth (mm)**	**Sup – Inf (°)**	**Ant – Post (°)**	**Depth (mm)**
N	50	50	50	50	50	50	50	50	50	10	10	10	10	10	10	10	10	10
Mean	20.03	12.13	21.60	0.07	12.91	21.10	-32.53	27.04	21.33	24.97	12.13	27.74	2.50	12.06	26.74	-31.17	26.53	28.55
SD	5.47	5.73	3.36	6.90	4.67	3.07	9.70	9.00	3.24	8.53	4.10	3.01	6.34	6.27	4.53	6.12	5.78	2.74
CI95%	1.52	1.59	0.93	1.91	1.29	0.85	2.69	2.49	0.90	5.29	2.54	1.87	3.93	3.89	2.81	3.79	3.58	1.70
Lower	18.51	10.54	20.66	-1.84	11.62	20.25	-35.22	24.54	20.44	19.68	9.59	25.87	-1.42	8.18	23.94	-34.96	22.95	26.86
Upper	21.55	13.72	22.53	1.98	14.21	21.95	-29.85	29.53	22.23	30.26	14.67	29.61	6.43	15.95	29.55	-27.37	30.11	30.25

CI95%: Confidence Interval of 95%

Lower: Lower range of values with a 95% confidence level

Upper: Upper range of values with a 95% confidence level

Negative (-) value with relation to superior – inferior angle indicates that the needle is entered from an inferior angle and proceded superiorly.

The following measurements were obtained for Group 1 on the dried paediatric skulls: For technique A, the needle was advanced for 24.40mm at a superior angle of 13.80° and an anterior angle of 16.20°; the needle was advanced 22.34mm for technique B at an almost horizontal level of 0.73° and from an anterior direction with an angle of 13.21°. In technique C, the needle had to be inserted at an inferior angle of 26.80°, which meant that the needle was advanced in a superior direction for 24.14mm at an anterior angle of 24.25°.

The average distance that the needle was advanced to reach the pterygopalatine fossa in the dried paediatric skulls, in Group 2, for technique A was 32.73mm. The needle was directed at a superior angle of 13.93° and from an anterior direction, at an angle of 12.43°. Technique B and C both had a negative angle with regard to the superior-inferior angle. Therefore, in both techniques the needle had to be advanced in an upward direction of 3.25° and 28.72° respectively, while the anterior angles were 9.06° and 23.37° respectively.

The following measurements were obtained for the Group 1 in the cadaveric specimens. The distance that the needle had to be inserted to reach the pterygopalatine fossa was very similar for the three techniques. These distances were on average, 21.6mm for technique A, 21.1mm for technique B and 21.33mm for technique C. The anterior-posterior angles for procedure A and B were also similar. Both had to be inserted from an anterior direction at angles of 12.13° and 12.91° respectively. Technique C had a much greater anterior angle of 27.04°. The superior-inferior angles differed greatly. These angles were on average at a downward angle of 20.03°, an almost horizontal angle of 0.07° and an upward angle of 32.53° for techniques A, B and C respectively

The measurements for the cadavers in Group 2 followed a similar pattern as for those in Group 1. The pterygopalatine fossa was slightly deeper while the distance differed only slightly between technique A (27.74mm), technique B (26.74mm) and technique C (28.55mm) ($p < 0.05$). The anterior-posterior angles for technique A and B differed greatly from those of technique C. There was a large variation between the superior-inferior angles that represented the differences in needle direction when progressed into the pterygopalatine fossa. In technique A the needle was advanced at a downward direction, at an angle of 24.97°, while in technique B the needle was inserted almost horizontally at an angle of 2.5° and in technique C the needle was advanced in a more superior or upward direction at an angle of 31.17°.

On the basis of the standard deviation and confidence interval analysis, the measurements obtained on both the dry skull and cadaver samples were compared. Technique A exhibited a statistical difference ($p < 0.05$; paired T-test) in both groups

1 and 2, when comparing the superior-inferior angle of the needle between the values of the skulls and the cadavers, whereas in Technique C a statistical difference ($p < 0.05$; paired T-test) was found when the depth to the pterygopalatine fossa in Group 2 was compared between the skulls and the cadavers. Technique B showed no statistical significance in both age groups when comparing the skulls to the cadavers. Consequently, the measurements of the angles and depth to the maxillary nerve at the foramen rotundum within the pterygopalatine fossa were combined, as seen in Table 2.2.

Table 2.2: Overall sample for technique B, results from Group 1 and 2 combined

	Age group 1			**Age group 2**		
	Sup – Inf (°)	**Ant – Post (°)**	**Depth (mm)**	**Sup – Inf (°)**	**Ant – Post (°)**	**Depth (mm)**
n	64	64	64	16	16	16
Mean	0.21	12.98	21.37	0.35	10.94	28.52
SD	6.48	5.42	4.22	5.85	6.20	5.65
CI95%	1.59	1.33	1.03	2.87	3.04	2.77
Lower	-1.37	11.65	20.34	-2.52	7.90	25.75
Upper	1.80	14.30	22.41	3.21	13.98	31.28

When technique B is used, the needle can be advanced horizontally for approximately 20mm in neonatal patients and 30mm for patients younger than one year. The needle should be advanced in a posterior direction, by just ‘walking’ or ‘sliding’ off the posterior border of the maxilla. The needle should be angled approximately 8 - 15°, at a point just anterior to the tragus of the contralateral external ear, to reach the pterygopalatine fossa. The following layers will be traversed by the needle towards the pterygopalatine fossa:

- Skin;
- Subcutaneous fat and fascia;
- Superficial layer of temporalis muscle;
- Deep layer of the temporalis muscle including the temporal fat pad located between the layers of the temporalis muscle and;
- Portion of fat pad continuous with the buccal fat pad.

The superficial temporal fat pad is important to note, to ensure that no anaesthetic is injected into this space. Should anaesthetic solution be accidentally injected into this space, fat necrosis could occur (Zuckerman *et al.,* 1990).

2.5 Discussion

Maxillary nerve blocks are being used for peri-operative analgesia after cleft palate repair in infants. Nerve blocks can dramatically reduce the consumption of opioid for postoperative pain relief (Mesnil *et al.,* 2010). However, the best approach for blocking the maxillary nerve in paediatric patients has yet to be established.

Technique A was found to be more difficult to simulate because the bony landmarks were difficult to palpate on the cadavers. This may explain the significant difference in angles in comparing the procedure on the skulls and the cadavers.

The depth to the pterygopalatine fossa using the infrazygomatic approach, technique C, was statistically different in Group 2. This was not surprising since there was more soft tissue to transverse in the cadavers.

The bony landmarks in technique B were more superficial and could be easily palpated. No statistical difference ($p > 0.05$) was observed when comparing the skull and cadaver measurements for either age group.

The results of this study show that technique B is the easiest and most reliable method of blocking the maxillary nerve, which corresponds with several other studies (Stajčić and Todorović, 1997; Captier *et al.,* 2009; Mesnil *et al.,* 2010). Stajčić and Todorović (1997), suggest that this technique is the safest approach and endorse this method since this approach reaches only the anterior part of the pterygopalatine fossa, which will prevent the needle from passing into the infra-orbital fissure and potentially damaging the infra-orbital contents.

Mesnil and co-workers (2010), evaluated the effectiveness of a bilateral suprazygomatic maxillary nerve block. The needle was inserted perpendicular to the skin, and advanced approximately 20mm to reach the greater wing of the sphenoid. The needle was then redirected and advanced 35mm – 45mm at a 20º anterior and 10º caudal direction toward the philtrum, to reach the pterygopalatine fossa. In this study the distance was measured from the level of the skin, unlike our study that measured from the frontozygomatic angle.

In comparison Captier and co-workers (2009), studied computed tomographic (CT) scans of 55 infants to determine the distance and trajectory of a needle from the frontozygomatic angle to the greater wing of the sphenoid bone. The distance measured was 24.1mm ± 2.7mm with a trajectory of 19.3° ± 5.3° in a forward direction. These measurements are similar to those obtained in our study although there was slight variance when comparing the angles, that can be attributed to the different measuring techniques used.

A limitation of this study was the exclusion of skin tissue depth since the cadaver measurements were taken from the level of the zygomatic arch after removal of the skin during dissection. However, this bony landmark is very superficial and is easily palpated. This depth is clinically negligible and the needle can be inserted using the depth obtained from this study as a guideline.

This technique needs to be tested in a clinical setting to ensure that the measurements in terms of the angles and depths at which the needle needs to be introduced to reach the pterygopalatine fossa is sufficiently accurate in order that a successful maxillary nerve block in infants can be achieved.

2.6 Conclusion

In conclusion, the suprazygomatic approach from the frontozygomatic angle (technique B**)** produces the most consistent results in paediatric cadavers. Using this approach, the needle can be advanced horizontally for approximately 20mm in neonates and 30mm for infants younger than one year. The needle should be advanced in a posterior direction, towards a point just anterior to the tragus of the contralateral external ear (this should be approximately between 8° and 15°) to reach the pterygopalatine fossa. The needle can be guided into the fossa by ‘walking’ off the posterior aspect of the maxilla.

2.7 References

Captier G, Dadure C, Leboucq N et al. (2009) Anatomic study using three-dimensional computed tomographic scan measurement for truncal maxillary nerve blocks via the suprazygomatic route in infants. *J Craniofac Surg* 20: 224 – 228

Doyle E, Hudson I. (1992) Anaesthesia for primary repair of cleft lip and cleft palate: a review of 244 procedures. *Paediatr Anaesth* 2: 139 – 145

Du Plessis M. (2010) Comparative study of the pterygopalatine fossa and its ganglion. MSc, University of Pretoria

Haberg C, Larson O, Milerad J. (1998) Incidence of cleft lip and palate and risks of additional malformations. *Cleft Palate Craniofac*. *J* 35: 40 – 45

Mesnil M, Dadure C, Captier G et al. (2010) A new approach for peri-operative analgesia of cleft palate repair in infants: the bilateral suprazygomatic maxillary nerve block. *Pediatric Anesthesia* 20: 343 – 349

Moore KL, Persaud TVN, Torchia MG. (2011) The developing human: Clinically oriented embryology. 9th edition. Saunders Elsevier, Philadelphia

Obayah GM, Refaie A, Aboushanab O et al. (2010) Addition of dexmedetomidine to bupivacaine for greater palatine nerve block prolongs postoperative analgesia after cleft palate repair. *Eur J Anaesthesiol* 27: 280 – 284

Rochette A, Dadure C, Raux O et al. (2009) Changing trends in paediatric regional anaesthetic practice in recent years. *Curr Opin Anaesthesiol* 22: 374 – 377

Singh B, Srivastava SK, Dang R. (2001) Anatomic considerations in relation to the maxillary nerve block. *Reg Anaesth* 26: 502 – 511.

Stajčić Z, Todorović L. (1997) Blocks of the foramen rotundum and the oval foramen: a reappraisal of extraoral maxillary and mandibular nerve injections. *Br J Oral Maxillo-fac Surg* 35: 328 – 333

Stechison MT, Brogan M. (1994) Transfacial transpterygomaxillary access to foramen rotundum, sphenopalatine ganglion, and the maxillary nerve in the management of atypical facial pain. *Skull Base Surgery* 4: 15 – 20

Strong EB, Buckmiller LM. (2001) Management of the cleft palate. *Facial Plast Surg Clin North Am* 9: 15 – 25

Thaller SR, Mele J, Hoyt J. (1995) The effect of antenatal surgery of craniofacial growth in a sheep model. *Plast Reconstr Surg* 96: 1 – 8

Welborn LG, Ramirez N, Oh TH et al. (1986) Postanesthetic Apnea and Periodic Breathing in Infants. *Anaesth* 65: 658 – 661

Zuckerman JD, Meislin RJ, Rothberg M. (1990) Injections for joint and soft tissue disorders, when and how to use them. *Geriatrics* 45: 45 – 52

3 Periorbital nerve blocks

3.1 Introduction

The supratrochlear, supraorbital and infraorbital nerves are collective known as the periorbital nerves (Silverman, 2015; Codner and McCord, 2016). The supraorbital and supratrochlear nerves are cutaneous branches of the ophthalmic division of the trigeminal nerve, while the infraorbital nerve is a cutaneous branch of the maxillary division of the trigeminal nerve (Standring, 2008).

The trigeminal nerve (CN V) is the largest cranial nerve and responsible for sensory innervation of the head and face, as well as motor innervation to the muscles of mastication. The skin of the face can be subdivided into three peripheral nerve fields which are associated with the three divisions of the trigeminal nerve. Based on the embryonic development, each division correlates with a developing facial process. This specific process will give rise to a specific part of the adult face. The ophthalmic nerve, the first and smallest division, is associated with the frontonasal process. The second division, the maxillary nerve, corresponds to the maxillary process, while the mandibular process is related with the third division, the mandibular nerve (Standring, 2008).

The ophthalmic nerve is a purely sensory nerve and associated with the frontonasal process. Three branches arise from the ophthalmic nerve: the frontal nerve, lacrimal nerve and nasociliary nerve. The frontal nerve is the largest branch of the ophthalmic nerve and enters the orbit through the superior orbital fissure. It then branches into two terminal cutaneous branches, the supraorbital and supratrochlear nerves (Suresh and Wagner, 2001; Suresh and Voronov, 2006; Standring, 2008; Voronov and Suresh, 2008; Osborn and Sebeo, 2010).

The supraorbital and supratrochlear nerves are responsible for cutaneous innervation of the forehead and scalp, anterior to the coronal suture. Accompanied by the supraorbital vessels, the supraorbital nerve exits the skull through the supraorbital notch or foramen, and continues to ascend towards the coronal suture

(Zide and Swift, 1998; Suresh and Voronov, 2006; Osborn and Sebeo, 2010). It divides into superficial medial branches that pierce the frontalis muscle to supply the anterior scalp, and the deeper lateral branches that travel within the areolar tissue, supplying the scalp with sensory innervation (Suresh and Voronov, 2006; Osborn and Sebeo, 2010; Byrne and Izzo, 2014).

The supratrochlear nerve innervates the skin of the upper eyelid and conjunctiva and ascends between the facial muscles of the forehead to the supply the skin of the lower forehead, near the median plane (Standring, 2008). Although most authors concur with the area of supply of the supratrochlear nerve, different statements with regard to the emerging pattern exist. Pulcini and Guerin (2007), as well as Osborn and Sebeo (2010), report that the supratrochlear nerve emerges from the supraorbital foramen, while Salam (2004) and Young et al. (2008) mention that the supratrochlear nerve emerges 10mm medial to the supraorbital foramen along the superior border of the orbit. This is in accordance with Suresh and Wagner (2001) who state that the supratrochlear nerve exits the orbit between the trochlea of the eye and the supraorbital foramen.

In a study conducted by Suresh and Voronov (2006), it was concluded that 97% of the skulls used in their study exhibited bilateral supratrochlear notches, and that the supratrochlear nerve rather exits the orbit at the superior orbital rim through a notch, than through the supraorbital foramen. Only one percent of the skulls had a unilateral foramen, while the remaining two percent had a notch on the one side and a foramen on the opposite side. Although the exact bony landmark through which the supratrochlear nerve emerges from the orbit is still questioned, the distribution of this nerve is not disputed (Bosenberg, 1999; Suresh and Voronov, 2006; Voronov and Suresh, 2008).

The second division of the trigeminal nerve, the maxillary nerve, is purely sensory and innervates the skin mostly derived from the embryonic maxillary process. After exiting the cranium through the foramen rotundum, several branches travel to the pterygopalatine ganglion as it passes through the pterygopalatine foramen towards the orbital cavity. It passes through the inferior orbital fissure, gives rise to the zygomatic nerve, and travels through the infraorbital canal as the infraorbital nerve (Dubash *et al.,* 2006; Moore and Dalley, 2006; Standring, 2008).

The infraorbital nerve gives rise to the middle and anterior superior alveolar nerves as it traverses the infraorbital canal. These nerves contribute to the sensory innervation of the anterior gingiva and maxillary teeth through the alveolar plexus (Zide and Swift, 1998; Dubash *et al.,* 2006; Moore and Dalley, 2006; Bhargava *et al.,* 2011). As soon as the infraorbital nerve emerges onto the face through the infraorbital foramen, it branches into external nasal, internal nasal, inferior palpebral and superior labial nerves (McAdam *et al.,* 2005; Dubash *et al.,* 2006; Moore and Dalley, 2006; Belvis *et al.,* 2007; Voronov and Suresh, 2008).

The aforementioned branches of the infraorbital nerve are responsible for cutaneous innervation of the lower eyelid with skin and conjunctiva, upper lip with skin and oral mucosa, the lateral part of the nose with the antero-inferior part of the nasal septum, the skin of the cheek, as well as the maxillary sinus and hard palate. The labial glands, as well as the premolar, canine and incisor maxillary teeth are also innervated by the branches of the infraorbital nerves (Zide and Swift, 1998; McAdam *et al.,* 2005; Suresh *et al.,* 2006; Moore and Dalley, 2006; Belvis *et al.,* 2007; Voronov and Suresh, 2008; Kim, 2009; Wells, 2010; Bhargava *et al.,* 2011).

As with the supratrochlear and supraorbital nerves, the infraorbital nerve is accompanied by a vascular bundle as it emerges onto the maxilla. The close proximity of the infraorbital artery and ~vein to the infraorbital nerve needs to be noted during the performance of an infraorbital nerve block (Suresh *et al.,* 2006; Voronov and Suresh, 2008; Bhargava *et al.,* 2011). According to Suresh and co-workers (2006), the infraorbital nerve emerges more superficially from the infraorbital foramen than the vascular bundle, and can therefore be more easily targeted.

Several authors describe the location of the infraorbital foramen as being in line with the middle of the pupil for the paediatric and adult populations, (Bosenberg, 1999; McAdam *et al.,* 2005; Peltier, 2006; Suresh *et al.,* 2006; Belvis *et al.,* 2007; Voronov and Suresh, 2008; Kim, 2009; Wells, 2010). However, a few additional descriptions are provided in the literature:

- The infraorbital foramen is located at the point where the vertical line through the pupil intersects with a horizontal line through the alae of the nose (Eipe *et al.,* 2006).
- The midpoint of the pupil is approximately 20mm from the midline, according to Kim (2009), as is the infraorbital foramen.
- Wells (2010) indicates that the infraorbital foramen is in the mid-pupillary line, 10mm below the infraorbital rim and approximately 25mm lateral to the midline of the face.
- Authors such as McAdam's and co-workers (2005) only mention that the infraorbital foramen is located at the floor of the orbital rim, in line with the pupil.

Other methods for establishing the location of the infraorbital foramen include:

- Rajamani (2007) uses a surface landmark, approximately midway along a line drawn from the angle of the mouth to the midpoint of the palpebral fissure.
- Peltier (2006) used the line between the angle of the mouth and the pupil. The infraorbital foramen can be palpated where this line intersects with the infraorbital rim.
- Using computed tomography (CT) scan images, Suresh and Voronov (2006) state that the infraorbital foramen can be found approximately 25mm from the midline, at the floor of the orbital rim, inferior to the pupil.
- The infraorbital foramen will be situated 4 – 7mm below the orbital rim, on a line drawn inferiorly from the medial limbus of the iris (Zide and Swift, 1998).
- "Just inferior to the orbit, slightly nasal to an imaginary line drawn through the middle of the infraorbital rim" (Salam, 2004).

Suresh and co-workers (2006) used CT scans to develop a mathematical formula to assist with determining the position of the infraorbital foramen. Based on the evaluation of the scans, they determined that the age of the patient plays a very important role in the variation with regard to the distance of the infraorbital foramen from the midline. Their formula 21.3 + 0.5 x age (in years), is used to determine the distance (in mm) from the midline, where the infraorbital foramen is located below the infraorbital rim.

In accordance, Bosenberg (1999) also mentions that the exact location of the infraorbital foramen is dependent on the age of the patient. The foramen is located inferior to the orbital rim, in line with the midpoint of the pupil. This landmark can be easily palpated 5mm inferior to the junction of the medial and middle thirds of the orbital rim. However, due to the difficulty in palpating this foramen in neonates and infants, a different technique can be used. Bosenberg and Kimble (1995) indicate that the location of the infraorbital foramen is half the distance on the line from the angle of the mouth to the palpebral fissure (15mm), and a quarter of the distance (7.5mm) from the nasal alae.

Due to the several different techniques being used to locate the infraorbital foramen, a standardised technique to locate this foramen in neonates and infants needs to be developed using anatomical dissection to expose the nerve and determine its location using anatomical landmarks. This will facilitate more accurate and effortless blocking of the infraorbital nerve in paediatric patients.

3.1.1 Indications

Silverman (2015) states: “Blockade of the periorbital nerves (supraorbital, supratrochlear, and infraorbital) is useful for surgical anaesthesia of the face, treatment of painful facial conditions, and can provide diagnostic information for the possibility of neurolytic blocks and neuromodulatory techniques”.

Regional anaesthesia, specifically facial nerve blocks including supraorbital~, supratrochlear~ and infraorbital nerves, is used for abscess incision and drainage, closed reduction of fractures, as well as foreign body removal (Salam, 2004). However, most commonly, these nerve blocks are performed individually.

The supraorbital and supratrochlear nerve blocks are indicated for most surgeries of the superior eyelid and forehead (Pulcini and Guerin, 2007), or related to the treatment of neuralgias (Evans and Pareja, 2009), headaches (Levin, 2009; Blumenfeld *et al.,* 2013), or migraines (Caputi and Firetto, 1997), especially in adults.

In the paediatric population, patients subjected to craniosynostosis repairs, as well as awake procedures for deep brain stimulation for the treatment of dystonia, undergo supraorbital and supratrochlear nerve blocks (Adam and Jankovic, 2007). These nerve blocks can also be used for epidermal nevus excisions on the scalp and frontal craniotomies (Kim, 2009).

Bosenberg (1999) indicates the supraorbital and supratrochlear nerve blocks for minor surgical procedures of the head, which include removal of cysts and suture lacerations. He also refers to other craniofacial surgeries where several nerve blocks of the scalp are used in combination.

In a case reported by Suresh and Bellig (2004), peripheral nerve blocks were used on a critically ill low birthweight neonate that underwent an Ommaya reservoir placement for obstructive hydrocephalus, secondary to grade three intraventricular haemorrhage. Through the use of the supraorbital, great auricular and greater occipital nerve blocks, they effectively minimised the physiological responses to the experienced surgical stress without compromising haemodynamic stability.

For surgeries performed on the scalp, specifically anterior to the coronal suture, the supraorbital and supratrochlear nerve blocks can be utilised. These include anterior midline dermoid excisions, frontal craniotomies and ventriculoperitoneal shunts, as well as Ommaya reservoir placements and nevus excisions (Suresh and Voronov, 2006). Suresh and Wagner (2001) also indicate scalp nerve blocks such as blocking the supraorbital and supratrochlear nerves, for the excision of congenital skin lesions of the scalp. These include aplasia cutis, nevus sebaceus, haemangiomas and congenital nevi.

In rare cases, neuroendocrine tumours such as pheochromocytoma and paraganglioma are encountered in paediatric patients. Cohen *et al.* (2011) used a supraorbital nerve block, prior to a skull lesion excision, on a 14-year old patient.

Other procedures performed, using the supraorbital and supratrochlear nerve blocks, include supratentorial craniotomies (Hartley *et al.,* 1991), wound closure and anaesthesia for debridement (Byrne and Izzo, 2014), trabeculectomy surgeries (Tay *et al.,* 2006), as well as for postoperative analgesia.

From the literature, the infraorbital nerve block is most commonly indicated for the use in cleft lip repairs, especially in paediatric patients. This block is used either in combination with general anaesthesia, lighter sedation or administered for the treatment of postoperative pain (Bosenberg and Kimble, 1995; Bosenberg, 1999; Suresh and Voronov, 2006; Suresh *et al.,* 2006; Belvis *et al.,* 2007; Jonnavithula *et al.,* 2007; Rajamani, 2007; Kim, 2009; Prabhu *et al.,* 2009).

Nasal procedures such as rhinoplasty (McAdam *et al.* 2005), nasal septal repair (Kim, 2009) and nasal tip reconstruction (Belvis *et al.,* 2007) are also performed using the infraorbital nerve block. Voronov and Suresh (2008) commonly utilised this regional anaesthetic technique during endoscopic surgeries and cleft lip repairs, due to the adequate intra~ and postoperative pain relief achieved by administering this block.

Facial procedures performed using the infraorbital nerve block include mole removal (Belvis *et al.,* 2007), pulse dye laser for the removal of portwine stains, as well as the excision of skin lesions such as congenital nevus (Voronov and Suresh, 2008).

In a single report, McAdam and co-workers (2005) used the infraorbital nerve block for analgesic purposes in an 11-year old patient who underwent a pituitary tumour resection using a trans-sphenoidal approach. Despite their stating that this was the first report on a trans-sphenoidal hypophysectomy with an infraorbital nerve block, the surgical team, patient and family were extremely satisfied with the outcome of the procedure, as well as the postoperative pain relief.

3.1.2 Contra-indications

Absolute contra-indications for the performance of any or all regional anaesthetic nerve blocks include patient refusal, or if the patients is uncooperative (Tay *et al.,* 2006), infection at the injection site, sensitivity or allergy to the anaesthetic agent used, or distortion of the anatomical landmarks as in the case of previous surgeries (Jonnavithula, 2007; Byrne and Izzo, 2012).

If a patient suffers from coagulopathy or bleeding disorders, as a safety precaution, regional nerve blocks should be avoided (Osborn and Sebeo, 2010). According to Salam (2004), should a physician be uncomfortable with the procedure, or lack the specific knowledge with regard to a specific nerve block, it is also considered as a contra-indication.

During trabeculectomy surgery where supraorbital nerve blocks were administered, Tay and co-workers (2006) excluded patients if they suffered from poor fixation due to strabismus (cross-eyed) or nystagmus (rapid uncontrolled eye movement).

Byrne and Izzo (2017) list the distortion of anatomical landmarks as a contra-indication for the performance of the infraorbital nerve block. This can be attributed to the importance of palpating the foramen prior to commencing with this block, and should the bony landmarks not be easily palpated, this block can be considered dangerous.

3.1.3 Step-by-step procedure

3.1.3.1 Supraorbital and supratrochlear nerve block

After studying the obtained literature, several different techniques to effectively block the supraorbital and supratrochlear nerves can be identified. These different methods can be classified using the following overall classification:

- Single site injection to block both the supraorbital and supratrochlear nerves in combination;
- Multiple site injection to block the supraorbital and supratrochlear nerves independently.

The different methods obtained from the literature will be grouped and discussed following the aforementioned classifications. Differences in entry points, population groups and techniques will be mentioned.

3.1.3.1.1 Single site injection

When performing a single site injection for the supraorbital and supratrochlear nerves, the most commonly described site is in relation to the midpoint of the pupil. This technique is used by Serra-Guillen *et al.* (2009) and Byrne and Izzo (2014) in the adult population, while Bosenberg (1999), Suresh and Voronov (2006), as well as Kim (2009), describe this technique for the use in paediatric patients.

The general technique used, involves the following steps:

- A vertical line through the pupil is visualised in order to locate the supraorbital neurovascular bundle;
- The supraorbital ridge is palpated at the reference point to confirm the location of the supraorbital notch / foramen;
- If the notch / foramen is positively identified, the anaesthetic solution is injected subcutaneously while gentle pressure is applied to decrease the formation of a possible haematoma (Suresh and Voronov, 2006; Kim, 2009: Byrne and Izzo, 2014);
- According to Bosenberg (1999), in the case of infant patients, the needle should be inserted mid-brow above the root of the nose.
- Byrne and Izzo (2014) state that the needle should be directed perpendicular to the supraorbital ridge in adults.

The abovementioned authors and studies refer to a single injection at a single site. However, Serra-Guillen *et al.* (2009) use a single site for blocking both nerves.

This is achieved by anaesthetising the supraorbital nerve at the same reference point, corresponding to the mid-point of the pupil. The needle is then withdrawn slightly, but, still using the same entry point, directed medially towards the nasal root in order to successfully block the supratrochlear nerve.

In accordance with the above statements, Suresh and Voronov (2006) use a single injection site to block the supratrochlear nerve separately. Once the supraorbital nerve is anaesthetised at the supraorbital notch, the needle is retracted to the level of the skin, and directed medially. After several millimetres, the anaesthetic solution is injected near the root of the nose, in order to block the supratrochlear nerve. However, this article does not indicate the exact amount of millimetres that the needle is advanced towards the root of the nose.

In an article published by Voronov and Suresh (2008), a slightly different single injection approach is explained. The supraorbital nerve is located by following the easily palpable supraorbital rim (in paediatric patients), from the midline in a lateral direction. After the anaesthetic solution is deposited in relation to the supraorbital neurovascular bundle, the needle is slightly withdrawn, directed medially towards the root of the nose, in order to block the supratrochlear nerve (Suresh and Wagner, 2001: Voronov and Suresh, 2008).

Zide and Swift (1998) use a single site, multiple injection technique:

- Several injections are performed along the easily palpatable supraorbital ridge;
- The needle is inserted from the lateral side, and advanced medially;
- Once the supraorbital notch is palpated, some anaesthetic fluid is deposited at this site, just below the orbicularis oculi muscle, after which the needle is advanced a few millimetres, where more anaesthetic fluid is deposited;
- The needle is then still directed medially, and advanced until the nasal bone is encountered where more anaesthetic fluid is deposited.

Similarly, Thomsen and Setnik (2005) use a comparable lateral approach:

- The supraorbital and supratrochlear nerves are blocked using a single injection in relation to the supraorbital rim;
- The medial limbus on the superomedial orbital rim is used as reference point, since the puncture site is located above this point;
- The needle is inserted from a lateral direction into the lateral edge of the middle third of the eyebrow, after which the needle is directed and advanced medially towards the canthus, where the upper and lower eyelids meet.

Salam (2004) uses a technique where the injection site is located just superior to the supraorbital rim, beneath the medial two thirds of the eyebrow. The anaesthetic solution is deposited, in order to successfully anaesthetise the cutaneous supraorbital and supratrochlear nerves. This allows for simultaneous blocking with no additional injection cites, or advancements needed.

3.1.3.1.2 Mutliple site injections

To ensure the accuracy of a nerve block, it is often debated that, for each nerve to be successfully blocked, that nerve needs to be approached specifically. Therefore, different injection sites are often used.

In order to only block the supraorbital nerve, the following techniques are described:

- In line with the middle of the pupil, a canal can be palpated under the orbital ridge. Small quantities of anaesthetic fluid is injected in the eyebrow, just superior to the supraorbital canal (Young *et al.,* 2008);
- The supraorbital foramen, with the supraorbital nerve, is located 25mm lateral to the midline of the face, along the upper orbital border (Salam, 2004);
- The supraorbital notch should be palpated and the needle inserted perpendicular to the skin, approximately 10mm medial to the supraorbital foramen. This is where the supraorbital nerve emerges from the orbit, as claimed by Osborn and Sebeo (2010);

- Also using the palpation of the supraorbital notch, Peltier (2006) indicates that the anaesthetic solution is continuously injected from that point, along the distribution of the nerve, until the patient experiences paraesthesia.

After the different methods for blocking the supraorbital nerve were investigated through a literature review, it was clear that no distinct method to locate the supraorbital notch / foramen has been identified and described, especially in the paediatric population. Therefore, anatomical research on the exact location of the supraorbital nerve emerging from the supraorbital notch / foramen is required. This will facilitate in the development of the most accurate and safest technique to block the supraorbital nerve.

Should the supratrochlear nerve be anaesthetised solely, different methods are again encountered:

- Young and co-workers (2008) state that the supratrochlear nerve emerges from the supratrochlear foramen, located 10mm medial to the supraorbital foramen, near the medial edge of the eyebrow. The needle should be inserted superior to this point, within the eyebrow;
- In accordance, Salam (2004) also states that the supratrochlear nerve should be anaesthetised by injecting anaesthetic solution 10mm medial to the supraorbital foramen, along the supraorbital margin;
- A finger’s breadth medial to the supraorbital nerve, is the distance that should be used should the supratrochlear nerve be blocked as it emerges above the eyebrow. This can be done, and a medial extension of the supraorbital nerve block can be performed, according to Osborn and Sebeo (2010);
- Peltier (2006) indicates that the intersection between the nose and the supraorbital ridge is a suitable point to inject the anaesthetic solution in order to block the supratrochlear nerve. This point corresponds to the superomedial corner of the orbit.

A standardised method to block the supratrochlear nerve in the paediatric population needs to be developed, by accurately determining the exact location of the supratrochlear nerve.

3.1.3.2 Infraorbital nerve block

In order to effectively block the infraorbital nerve at the infraorbital foramen, two well described techniques are used: the extra-oral approach and the intra-oral approach. Although the intra-oral approach is preferred for the adult population, Voronov and Suresh (2008) indicate their preference for this approach in the paediatric population, due to the risk for hematoma formation being lower. However, Bosenberg (1999) states: “The author believes that the intra-oral approach is contra-indicated in neonates and small infants because of the proximity of the orbit”. Therefore, in this research study only the extra-oral approach is considered for paediatric patients.

Several methods for blocking the infraorbital nerve are described, with the majority being a transcutaneous approach. The technique described by Bosenberg and Kimble (1995) is the most commonly indicated method for the use in neonates and infants:

- The site for needle injection is approximately midway along a line drawn from the middle of the palpebral fissure to the angle of the mouth;
- The needle is then introduced and advanced perpendicular to the skin until the bone is reached;
- After confirming that a blood vessel has not been punctured, the needle is slightly withdrawn, and the anaesthetic solution is deposited;
- Should resistance be encountered during the injection, the needle tip is adjusted slightly;
- Pressure is then applied to the injection site for approximately five minutes.

Both Eipe and co-workers (2006), as well as Voronov and Suresh (2008), describe a similar technique for the use on neonates and infants:

- The infraorbital foramen is located through gently palpating the floor of the orbital rim;
- In order to prevent the needle from advancing superiorly, a finger is placed at the level of the infraorbital foramen, while the needle is inserted at a right angle to the skin;
- The needle is advanced until bony resistance is felt, without entering the infraorbital canal, in order to prevent intraneural injection;
- After negative aspiration, the anaesthetic solution is injected with gentle pressure being recommended at the injection site.

Belvis and co-workers (2007) use the same technique, with clear reference to the patient being placed in the supine position, and the foramen being located by palpating the rim of the orbital floor. In a different technique, Salam (2004) indicates that the needle should be inserted approximately 10mm inferior to the infraorbital foramen and advanced superolaterally. This route will ensure that the needle does not pass through the infraorbital foramen and enter the orbit.

For adult patients, Zide and Swift (1998) describe this technique:

- An imaginary inverted “V” is used as reference point between the nasal labial fold and the alar base inset;
- At the centre of the inverted “V” a small point is marked;
- While holding the needle much like a pen, the non-dominant hand is placed on the infraorbital rim;
- With the patient looking straight ahead, the needle is passed through the marked reference point in an upward and lateral direction to approximately 5 – 7mm below the infraorbital rim;
- The needle tip should be in line with the medial limbus of the iris, when the anaesthetic fluid is injected.

A different approach is explained by Wells (2010):

- The infraorbital foramen is identified;
- The needle vertically punctures the skin approximately 5mm inferior to the foramen and aimed superiorly;

- The needle is then advanced superiorly and posteriorly, until the bone is reached;
- The needle is withdrawn and aspiration is performed to ensure no blood is drawn;
- The anaesthetic is then deposited near and around the foramen. However, care should be taken in order to prevent injection into the infraorbital foramen.

In order to successfully block the infraorbital nerve, the exact location of the infraorbital foramen needs to be found and the correctness of the most commonly described inferior approach to the foramen be determined and evaluated, specifically for the paediatric population.

3.1.4 Anatomical pitfalls

From the literature, the biggest anatomical pitfall encountered relates to the exact location on the bony landmarks. The location of the supraorbital foramen / notch, supratrochlear notch, as well as the infraorbital foramen, is important to note. Zaizen and Sato (2014) make this very relevant statement: “Traditionally, maxillary nerve blocking has been performed using external anatomic landmarks. However, this morphological approach to nerve identification may be confounded by anatomic variability”. Due to anatomic variability, research studies need to be conducted, especially in the paediatric population.

In a study conducted by Hwang and co-workers (2013), they state that from four anatomical studies led by other authors, they concluded that in their respective studies, the supraorbital notch / foramen was in the same sagittal plane as the infraorbital foramen. Yet, Hwang *et al.* (2013) report that the infraorbital foramen is 5.6mm lateral to the sagittal plane of the supraorbital notch / foramen in their study.

Using CT scans, Suresh and co-authors (2006) evaluated the exact location of the infraorbital foramen in 48 patients. All patients, except three, exhibited intra-patient variability with regard to the position of the infraorbital foramen on the left and right sides. Variation based on the age of the patient was also encountered. Therefore, the exact location of the infraorbital foramen for specific age groups needs to be evaluated and documented.

The direction of the infraorbital canal, extending laterally and upward from the infraorbital foramen, is also important to note. Bhargava *et al.* (2011) concur with the superolateral direction of the canal from the anterior maxilla. Should the needle be entered into the canal during the performance of a nerve block, damage to the neurovascular structures could occur. Therefore, the direction and depth the needle travels is important to note. Hwang *et al.* (2013) report that by using CBCT images, they could establish that the soft tissue thickness over the infraorbital foramen is approximately 12mm in their Korean sample. However, this needs to be evaluated in paediatric patients as well.

Another anatomical pitfall encountered during periorbital nerve blocks is the lack of knowledge on the related neurovascular structures. Evans and Pareja (2009) describe the possible occurrence of vascular compression of the supraorbital and supratrochlear nerves due to the adjacent and closely related supraorbital and supratrochlear arteries, respectively.

Byrne (2012) also placed important emphasis on the proximity of vascular structures, such as the facial artery and ~vein, to the infraorbital foramen. For this reason, to ensure that the needle is not positioned within a blood vessel, it is important to aspirate as the needle is advanced.

Osborn and Sebeo (2010) stated that “A careful identification of the discussed anatomic landmarks will help prevent injection into this nerve”. Although the statement was made in reference to the facial nerve and possible paralysis during “scalp blocks”, it can be applied to the performance of all regional anaesthetic techniques.

3.1.5 Complications and side-effects

Even though complications for these regional nerve blocks are rare (Osborn and Sebeo, 2010), most of the complications observed in the literature can be attributed to a lack of anatomical knowledge. Suresh and Voronov (2006), as well as Osborn and Sebeo (2010), mention that haematoma formation due to vascular injection or intraneural injection can happen due to the incorrect placement of the needle. In order to minimise the possible risk of periorbital haematoma formation, the anaesthetic solution should be injected above the eyebrow, between the skin and the skull (Bosenberg, 1999).

Although it is a rare complication, eye globe damage could possibly occur during the performance of the periorbital nerve blocks (Voronov and Suresh, 2008). Therefore, the distance that the needle travels should be carefully monitored. This can be achieved and regulated by placing a finger at the level of the specific foramen in order to monitor the distance the needle traverses (McAdam *et al.,* 2005; Voronov and Suresh, 2008). Should orbital injection occur, it can result in the patient experiencing excessive pain, diplopia, exophthalmos, or even blindness (Rajamani *et al.,* 2007).

Oedema and ecchymosis can occur during the performance of the supraorbital and supratrochlear nerve blocks (Zide and Swift, 1991; Suresh and Wagner, 2001; Byrne and Izzo, 2012). This is due to the loose areolar tissues of the eyelid, as mentioned by Suresh and Wagner (2001). However, this possible complication can be minimised by applying gentle pressure to the area after the nerve block has been performed (Suresh and Wagner, 2001). Kim (2009) also reports that gentle pressure to the anaesthetised area can result in a decreased possibility for haematoma formation.

Pulcini and Guerin (2007) advise that nerve damage should be avoided in all circumstances. This can be achieved by ensuring that the needle makes contact with the bone approximately 10mm from the foramen or notch from where the targeted nerve will emerge. They also report on the possibility of transitory palpebral ptosis that can occur during the supraorbital nerve block, due to the anaesthetic agent diffusing towards levator palpebrae superioris muscle.

Complications, some very rare, that can be experienced during the performance of any nerve block include:

- Systemic toxicity resulting in light-headedness;
- Tinnitus;
- Visual disturbances;
- Seizure or comas (Salam, 2004);
- Allergic reaction to the anaesthetic solution (Brennan, 2009; Byrne and Izzo, 2012);
- Infection;
- Failure to successfully anaesthetise (Byrne and Izzo, 2012).

Possible side effects that can occur due to the infraorbital nerve block, specifically, include erythema on the cheek. One patient in a study conducted by Jonnavithula *et al*. (2007) experienced this. In that study the erythema was visible on the patient's cheek for approximately three hours after the block was performed. Temporary blindness can also occur due to the retrograde passing of the anaesthetic solution into the orbit. This can be very alarming to the patient, and can be avoided by ensuring that the injection pressure is kept low (Wells, 2010).

Children, as well as their parents, need to be made aware of the fact that the upper lip will be numbed during the performance of the infraorbital nerve block as its sensory distribution will be disrupted. This numbness of the upper lip might result in problems with oral feedings, as well as the possibility of the child biting on the lip without experiencing immediate pain (Suresh and Voronov, 2006; Belvis *et al.,* 2007: Rajamani *et al.,* 2007; Kim, 2009).

Suresh and Wagner (2001) state: "The use of local anaesthetics in peripheral nerve blocks can reduce the need for potent postoperative analgesics during scalp lesion excisions. However, careful attention to the anatomy and innervation is necessary to identify the appropriate nerves to each area of the scalp.” By means of anatomical research, possible anatomically related complications can be minimised.

3.2 Aims

The following aims will be addressed in this research chapter:

3.2.1 To determine the position of the periorbital foramina / notches and their distances from easily identifiable bony landmarks on dry paediatric skulls.

3.2.2 To determine the position, course and any variation of the periorbital nerves on a paediatric cadaver sample.

3.2.3 To formulate standardised methods for blocking the periorbital nerves in the paediatric population using anatomical landmarks.

3.3 Materials and Methods

a. To determine the position of the periorbital foramina / notches and its distances from easily identifiable bony landmarks on dry paediatric skulls.

In order to determine the exact position of the periorbital foramina / notches, 25 paediatric skulls from the Pretoria bone collection, housed at the Department of Anatomy, University of Pretoria, were used. All the skulls were placed on a horizontal flat surface in the Frankfurt horizontal plane. High quality photographs were taken from an anterior view and imported into Image Tool V3.0, an image software program, in order to accurately determine the distances of the bilaterally evaluated bony landmarks.

The following bony landmarks were identified on the digital photographs and used as reference points for the determination of the respective distances, as seen in Figure 3.1.

- A – Supratrochlear notch / foramen;
- B – Supraorbital notch / foramen;
- C – Infraorbital foramen;
- D – Inferior orbital margin;
- E – Midline.

In order to determine the exact locations of the periorbital foramina / notches, the following distances were measured (Figure 3.1):

- The distance from the supratrochlear notch / foramen (A) to the midline of the skull (E);
- The distance from the supraorbital notch / foramen (B) to the midline of the skull (E);
- The distance between the infraorbital foramen (C) and the inferior orbital margin (D);
- The distance from the infraorbital foramen (C) to the midline of the skull (E).

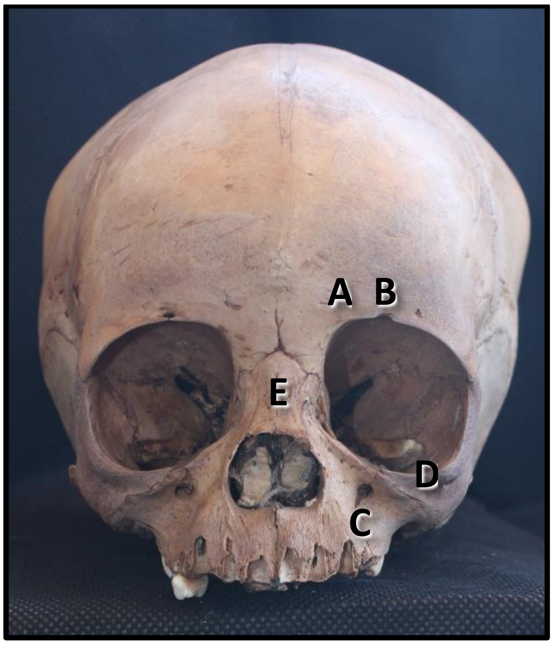


Figure 3.1: Anterior view of a paediatric skull indicating the landmarks to evaluate the periorbital foramina / notches.

To effectively describe the periorbital bony landmarks related to the supraorbital and supratrochlear nerve blocks, the exact shape of these respective bony landmarks were also evaluated and described.

b. To determine the position, course and any variation of the periorbital nerves on a paediatric cadaver sample.

In order to determine the position, course or any variations in the distribution of the periorbital nerves, 50 paediatric cadavers (41 neonates and 9 infants) were dissected bilaterally in order to effectively visualise and describe the position of emergence of the nerves, as seen in Figure 3.2.

All the cadavers were placed in the supine position and dissected bilaterally, superior and inferior to the orbit. The skin was reflected superiorly (for the supraorbital and supratrochlear nerves) and inferiorly (for the infraorbital nerves). Muscles of facial expression and additional soft tissue were carefully removed in order to expose the nerves as they emerged from the respective bony landmarks.

The following bony~ and soft tissue landmarks were identified and used for the distance measurements using a Vernier digital calliper (accuracy of 0.01mm), as seen in Figure 3.2:

- A – Supratrochlear notch / foramen with the emerging supratrochlear nerves;
- B – Supraorbital notch / foramen with the emerging supraorbital nerves;
- C – Infraorbital foramen with the emerging infraorbital nerves;
- D – Inferior orbital margin;
- E – Midline.

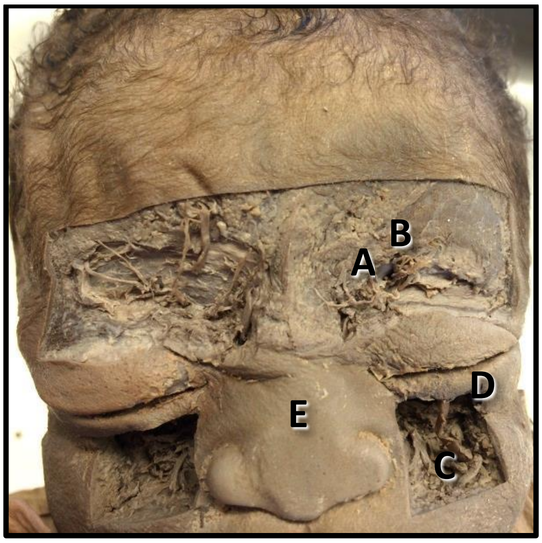


Figure 3.2: Anterior view of a paediatric cadaver indicating landmarks used to evaluate the periorbital nerves emerging from the periorbital foramina / notches

In order to establish an effective method of blocking the periorbital nerves, the exact location of the periorbital nerves were determined by means of the following measurements:

- The distance from the supratrochlear notch / foramen (A) where the supratrochlear nerves emerge, to the midline of the face (E);
- The distance from the supraorbital notch / foramen (B) where the supraorbital nerves emerge, to the midline of the face (E);
- The distance between the infraorbital foramen (C) where the infraorbital nerves emerge, and the inferior orbital margin (D);
- The distance from the infraorbital foramen (C) to the midline of the face (E).

These measurements, with distance determination, will assist in the development of a standardised method to safely and effectively block the periorbital nerves in the paediatric population.

c. To formulate standardised methods for blocking the periorbital nerves in the paediatric population

The results obtained from (a) and (b), as well as the most commonly performed techniques obtained from the literature, were compared and investigated to determine a standardised method of blocking the periorbital nerves in paediatric patients.

All the measurements obtained in (a) and (b) for both the left and right sides of the osteological and cadaveric specimens were compared. The measurements obtained from the osteological skull specimens are considered as the “ideal” values, based on the bony landmark being easily identifiable, accessible and measureable. These values were then compared with the “real” values obtained from the cadaveric specimens, based on the simulation of patients in a clinical setting. Thus, when these measurements were compared, the final obtained values for blocking the periorbital nerves in the paediatric population can be considered as being anatomically accurate.

Knowledge about the distances between the periorbital nerves and specific landmarks will assist anaesthesiologists and relevant clinicians to safely perform these techniques in paediatric patients. To further assist with this determination, the breadth of the fingers on the right hand of each dissected cadaver was measured as follows:

- Breadth of the medial four fingers at the proximal interphalangeal joint;
- Breadth of the medial three fingers at the proximal interphalangeal joint;
- Breadth of the medial two fingers at the proximal interphalangeal joint;
- Breadth of the 5th digit / digitus manus minimus (little finger) at the proximal interphalangeal joint;
- Breadth of the thumb at the interphalangeal joint.

To facilitate and assist medical practitioners to effortlessly settle on correct distances that need to be used, a correlation between the combined distances obtained in (a) and (b), and the breadth of the fingers on the right hand of each cadaver was determined. Through this correlation, the determination of the distances where the needle needs to be entered, will be more easily ascertained without the need of measuring equipment. This will result in a simpler and more effective method of blocking the periorbital nerves.

3.3.3 Statistical analysis

In order to accurately compare the skulls and the cadavers, the sample was divided into two age groups:

- Group 1 consisted of skulls and cadavers of neonates (0 – 28 days after birth);
- Group 2 included the skulls and cadavers of infants between 28 days and one year of age.

For the evaluation of the periorbital nerves and related bony landmarks, 50 cadavers and 25 skulls were included in the sample. In this sample, Group 1 included nine neonatal skulls and 41 neonatal cadavers, while 16 infant skulls and nine cadavers were measured for age Group 2. All measurements obtained were captured in a MS Excel data sheet, in order to statistically analyse the obtained data.

All obtained measurements with regard to the bony landmarks and the periorbital nerves for both aims (a) and (b) were investigated by means of a SAS® version 9.3 statistical program through the following descriptive statistics:

- The average or mean of each measurement;
- The standard deviation in order to establish the range of the sample;
- The 95% confidence interval in order to establish the true population value for the statistic value, including upper and lower ranges.

All the measurements obtained for (a) and (b) were gathered bilaterally, and a paired T-test performed in order to determine whether there is a statistically significant difference between the right and left sides of the specimen. A p-value of < 0.05 was regarded as statistically significant.

The final aim (c) of this research chapter was to formulate standardised methods of blocking the periorbital nerves in the paediatric population. Through the exact determination of the location of the supratrochlear, supraorbital and infraorbital nerves, this could be done.

Most commonly, the periorbital nerves are located based on the palpation of the respective bony landmarks and the distances from the midline to these bony landmarks. The osteological measurements obtained in the first aim are considered the “ideal” values, since these measurements were obtained from macerated skulls, which allowed for clear observations. The cadaveric measurements obtained in the second aim are perceived as the “real” values, since these represent the values that will be used in a clinical setting. The descriptive statistics for the obtained distances for the first and second aims were compared, using a student T-test ($p < 0.05$) in order to ascertain that the cadaveric “real” values do not differ from the “ideal” osteological values.

The “approved” cadaveric distances were then compared to the breadth of the fingers on the right hand of each individual cadaveric specimen in order to establish the best technique for blocking the periorbital nerves in the paediatric population. Population correlation coefficient analysis (Pearson) was used to determine whether a relationship exists between the two sets of variables. A Pearson correlation coefficient is used to determine the strength of the relationship between two variables (McDonald, 2014). For this research study, a correlation coefficient of greater than 0.80 ($R > 0.80$) was considered as a positive correlation between the two sets of variables.

3.4 Results

As indicated in Chapter 1, no statistically significant difference ($p > 0.05$) was detected between the left and right side measurements obtained from the specimens, resulting in all the measurements of the right and left sides being combined as a total sample.

The first aim of this chapter was to provide a detailed description of periorbital nerves and their respective bony landmarks on osteological specimens. The results of this aim will be subdivided according to specific age groups.

3.4.1 Measurements for periorbital nerves on osteological specimens

3.4.1.1 Measurements for neonatal skulls

The measurements for the nine Group 1 neonatal skulls (0 – 28 days after birth) are displayed in Table 3.1. All measurements were obtained bilaterally, and combined as described previously.

Table 3.1: Distance and placement of periorbital landmarks for Group 1 skulls

	Distance SO - M	**Distance ST - M**	**Distance IO - Orbit**	**Distance IO - M**
n	18	18	18	18
Mean	13.85	8.86	3.47	13.41
SD	2.76	1.46	1.14	2.30
CI95%	1.28	0.67	0.53	1.06
Lower	12.57	8.19	2.94	12.35
Upper	15.12	9.54	4.00	14.47

Key:

SO: Supraorbital
M: Midline
ST: Supratrochlear
IO: Infraorbital
CI95%: Confidence interval of 95%
Lower: Lower range of values with a 95% confidence interval
Upper: Upper range of values with a 95% confidence interval

For the nine neonatal skulls evaluated in Group 1, it can be observed in Table 3.1 that the supraorbital bony landmark (foramen or notch) is, on average, 13.85mm (range: 12.57mm – 15.12mm) from the midline, in close comparison to the infraorbital foramen which is located 13.41mm (range: 12.35mm – 14.47mm) from the midline.

In order to more effectively classify the opening through which the periorbital nerves (specifically the supraorbital and supratrochlear nerves) emerge from the skull, these bony landmarks were classified as being a foramen, notch or no specific bone feature present (Table 3.2).

Table 3.2: Classification of periorbital osteological features for neonatal skulls (Group 1)

	Supratrochlear	**Supraorbital**
n	18	18
1	0	0
2	8	11
3	10	7

Key:

1: Bony landmark is a foramen
2: Bony landmark is a notch
3: No specific osteological feature

From Table 3.2 it can be observed that a supraorbital notch is the most commonly encountered bony landmark (61.1%), while no specific osteological feature could be identified for the supratrochlear bony landmarks in 55.6% of the investigated neonatal skulls.

3.4.1.2 Measurements for infant skulls

The distance measurements obtained bilaterally from 16 infant (Group 2) skull specimens are displayed in Table 3.3. These skulls are all aged between 28 days and one year after birth.

Table 3.3: Distances and placement of periorbital landmarks for Group 2 skulls

	Distance SO - M	**Distance ST - M**	**Distance IO - Orbit**	**Distance IO - M**
n	32	32	32	32
Mean	18.92	12.39	5.50	17.74
SD	1.93	1.30	0.92	1.48
CI95%	0.67	0.45	0.32	0.51
Lower	18.25	11.94	5.19	17.23
Upper	19.59	12.84	5.82	18.25

Key:

SO: Supraorbital
M: Midline
ST: Supratrochlear
IO: Infraorbital
CI95%: Confidence interval of 95%
Lower: Lower range of values with a 95% confidence interval
Upper: Upper range of values with a 95% confidence interval

Similar to the neonatal skulls, the skulls evaluated for Group 2 display a close similarity with regard to the supraorbital and infraorbital bony landmarks measuring close to the same vertical plane, displaying only a 1.18mm discrepancy in the obtained distances (Table 3.3).

In order to effectively describe the bony landmarks from where the periorbital nerves emerge, these landmarks were examined and classified into three groups, as seen in Table 3.4. These landmarks are grouped as being either a foramen, notch or no specific osteological feature.

Table 3.4: Classification of periorbital osteological features for infant skulls (Group 2)

	Supratrochlear	**Supraorbital**
n	32	32
1	1	2
2	14	25
3	17	5

Key:

1: Bony landmark is a foramen
2: Bony landmark is a notch
3: No specific osteological feature

From Table 3.4 it can be observed that the supratrochlear bony landmark can most commonly be classified exhibiting no specific osteological feature in 53.1% of the infant skulls, while the supraorbital notch was observed in 78.2% of the infant skulls (Group 2) aged between 28 days and one year after birth.

3.4.2 Measurements for periorbital nerves on cadaveric specimens

3.4.2.1.Neonatal specimens

In Table 3.5 the measurements obtained bilaterally from 41 neonatal (Group 1, 0 – 28 days after birth) cadavers are displayed.

Table 3.5: Distances and placement of periorbital nerves for Group 1 cadavers

	Distance SO - M	**Distance ST - M**	**Distance IO - Orbit**	**Distance IO - M**
n	82	82	82	82
Mean	13.57	8.21	2.88	12.78
SD	3.57	2.33	0.88	2.87
CI95%	0.77	0.50	0.19	0.62
Lower	12.80	7.70	2.69	12.16
Upper	14.34	8.71	3.07	13.41

Key:

SO: Supraorbital nerve
M: Midline
ST: Supratrochlear nerve
IO: Infraorbital nerve
CI95%: Confidence interval of 95%
Lower: Lower range of values with a 95% confidence interval
Upper: Upper range of values with a 95% confidence interval

For the 41 neonatal cadavers dissected bilaterally, the supraorbital nerve is located 13.57mm (range: 12.80mm – 14.34mm) from the midline, while the infraorbital nerve is located 12.78mm (range: 12.16mm – 13.41mm) lateral to the midline of the face.

The bony landmark from where the supraorbital and supratrochlear nerves emerge was also observed and categorised in order to better classify these bony landmarks. These landmarks for Group 1 cadavers are classified as either being a foramen, notch or no specific osteological feature present (Table 3.6).

Table 3.6: Classification of periorbital osteological features for neonatal cadavers (Group 1)

	Supratrochlear	**Supraorbital**
n	82	82
1	6	39
2	2	19
3	74	24

Key:

1: Nerve emerges from a foramen
2: Nerve emerges from a notch
3: No specific osteological feature from where nerve emerges

From Table 3.6 it can be seen that the majority of supratrochlear nerves emerge from a bony landmark with no distinct osteological features in 90.2% of the neonatal cadavers. With regard to the supraorbital nerve, the majority (47.6%) emerge through a supraorbital foramen.

3.4.2.2 Infant specimens

The measurements collected from nine infant (Group 2) cadavers dissected bilaterally, are displayed in Table 3.7.

Table 3.7: Distances and placement of periorbital nerves for Group 2 cadavers

	Distance SO - M	**Distance ST - M**	**Distance IO - Orbit**	**Distance IO - M**
n	18	18	18	18
Mean	16.77	10.32	3.24	15.76
SD	3.21	2.62	0.84	2.85
CI95%	1.48	1.21	0.39	1.32
Lower	15.29	9.11	2.85	14.44
Upper	18.25	11.53	3.63	17.07

Key:

SO: Supraorbital nerve
M: Midline
ST: Supratrochlear nerve
IO: Infraorbital nerve
CI95%: Confidence interval of 95%
Lower: Lower range of values with a 95% confidence interval
Upper: Upper range of values with a 95% confidence interval

From Table 3.7, it is evident that the supraorbital and infraorbital nerves each emerge on average, within a 1.01mm distance from each other (on the same vertical plane of 10mm), with the infraorbital nerve located 3.24mm (range: 2.85mm – 3.63mm) below the inferior orbital rim.

The classifications of the bony landmarks from which the supratrochlear and supraorbital nerves emerge are exhibited in Table 3.8.

Table 3.8: Classification of periorbital osteological features for neonatal cadavers (Group 2)

	Supratrochlear	**Supraorbital**
n	18	18
1	2	12
2	2	4
3	14	2

Key:

1: Nerve emerges from a foramen
2: Nerve emerges from a notch
3: No specific osteological feature from where nerve emerges

From Table 3.8 it can be ascertained that in 77.8% of the specimens, no distinct osteological feature was observed where the supratrochlear nerve emerged, while the supraorbital nerve emerged from a foramen in 66.7% of the cases.

3.4.3 Periorbital nerve blocks in paediatric patients

In the third (c) aim of this research chapter, the most effective method for blocking the periorbital nerves in the paediatric population is determined by comparing the results from the first (a) and second (b) aims, and comparing those values with those of the breadth of the fingers on the right hand of each cadaver. This will allow for a more standardised – and practical in a clinical setting – technique of blocking the periorbital nerves in the paediatric population.

3.4.3.1 The periorbital nerve blocks in neonates

In order to effectively establish the most accurate method to block the periorbital nerves, the distances obtained from the osteological specimens, the “ideal” values and those obtained from the cadaveric specimens, the “real” values were directly compared for the neonatal cadavers, as seen in Figure 3.3.

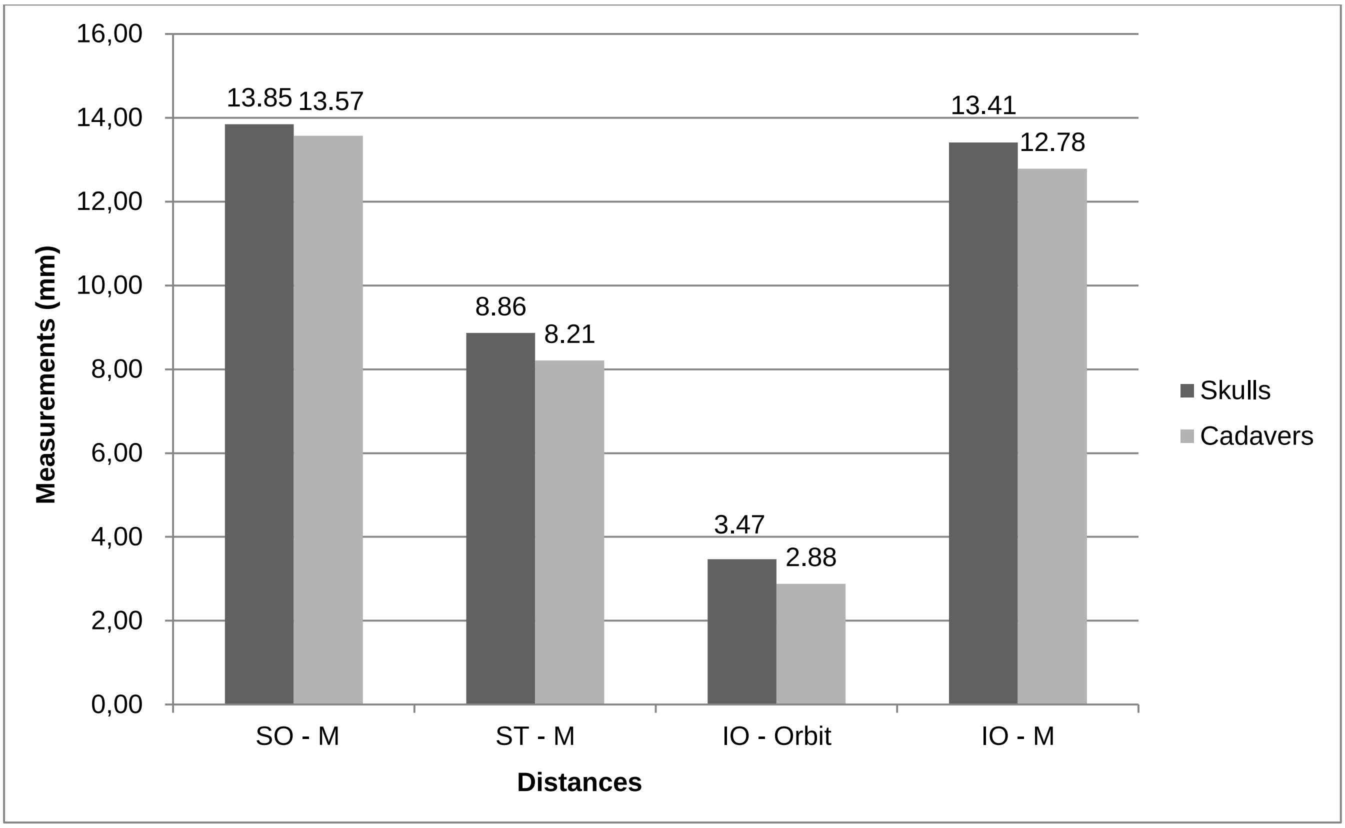


Figure 3.3: Direct comparison of measurements obtained from Group 1 skulls and cadavers

[SO: Supraorbital nerve; M: Midline; ST: Supratrochlear nerve; IO: Infraorbital nerve]

When evaluating the measurements in Figure 3.3, it appears that the values for the skulls and cadavers are closely comparable. This was proved correct by means of a non-parametric Kruskal-Wallis test, where no statistically significant difference ($p > 0.05$) was observed when the measurements obtained from the skulls were compared with those of the cadavers. The exception is the distance between the infraorbital foramen and the midline of the face, as seen in Table 3.9.

Table 3.9: p-values for non-parametric Kruskal-Wallis comparison between the skulls and cadavers of Group 1

	Distance SO - M	**Distance ST - M**	**Distance IO - Orbit**	**Distance IO - M**
p-value	0.5154	0.1113	0.2124	0.0264

Key:

SO: Supraorbital nerve
M: Midline
ST: Supratrochlear nerve
IO: Infraorbital nerve

From Table 3.9 it can be observed that no statistical difference is found between the “ideal” and the “real” values for the neonatal group, except for the distance from the infraorbital foramen to the midline of the face. Based on no statistically significant difference being observed, the total sample was combined between the skulls and the cadavers for the first three measurements obtained, as seen in Table 3.10.

Table 3.10: Distances obtained for the combined neonatal sample

	Distance SO - M	**Distance ST - M**	**Distance IO - Orbit**
n	100	100	100
Mean	13.62	8.33	2.99
SD	3.43	2.21	0.95
CI95%	0.67	0.43	0.19
Lower	12.95	7.89	2.80
Upper	14.29	8.76	3.18

Key:

SO: Supraorbital nerve
M: Midline
ST: Supratrochlear nerve
IO: Infraorbital nerve
CI95%: Confidence interval of 95%
Lower: Lower range of values with a 95% confidence interval
Upper: Upper range of values with a 95% confidence interval

In the combined neonatal sample, it can be observed from Table 3.10 that the supraorbital nerve emerges 13.62mm (range: 12.95mm – 14.29mm) from the midline, while the supratrochlear nerve is located 8.33mm (range: 7.89mm – 8.76mm) lateral to the midline. The infraorbital nerve is located at a point 2.99mm (range: 2.80mm – 3.18mm) below the inferior orbital margin.

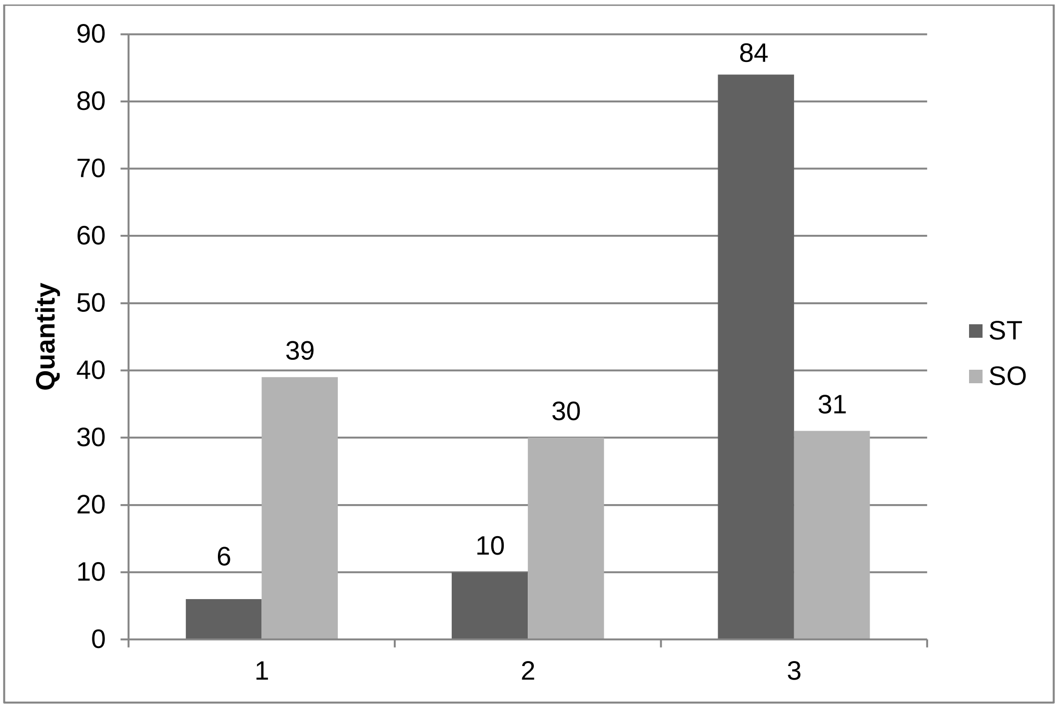


Figure 3.4: Direct comparison of periorbital bony landmark observations for the combined neonatal (Group 1) sample

[1: Periorbital foramen; 2: Periorbital notch; 3: No distinct osteological feature; ST: Supratrochlear nerve; SO: Supraorbital nerve]

From Figure 3.4 it is apparent that in most cases of the neonatal sample, no specific osteological feature is observed in the majority (84%) of the specimens with regard to the emergence of the supratrochlear nerve, while the supraorbital bony landmark categories are almost equally divided amongst the neonatal sample.

In Table 3.11, the average measurements with regard to the fingers on the right hand for each of the neonates are presented.

Table 3.11: Average breadth of the fingers on the right hand for Group 1

	4 fingers	**3 fingers**	**2 fingers**	**1 finger**	**Thumb**
n	41	41	41	41	41
Mean	24.05	18.33	11.96	5.44	7.37
SD	6.72	5.26	3.51	1.60	3.59
CI95%	2.06	1.61	1.08	0.49	1.10
Lower	22.00	16.72	10.88	4.95	6.28
Upper	26.11	19.94	13.03	5.93	8.47

Key:

CI95%: Confidence interval of 95%
Lower: Lower range of values with a 95% confidence interval
Upper: Upper range of values with a 95% confidence interval

In order to block the periorbital nerves in the neonatal population more easily, population correlation coefficients were determined to evaluate the relationship between the two sets of values.

Tables 3.12a and 3.12b display the values obtained after determining the Pearson correlation coefficients for the neonatal cadavers.

Table 3.12a: Pearson correlation coefficient values for Group 1 with regard to the supraorbital and supratrochlear measurements

	4 fingers	**3 fingers**	**2 fingers**	**1 finger**	**Thumb**
SO - M (R-value)	0.71	**0.73**	0.65	0.60	0.31
p-value	<.0001	<.0001	<.0001	<.0001	0.0521
ST - M (R-value)	0.63	**0.64**	0.60	0.50	0.19
p-value	<.0001	<.0001	<.0001	0.0008	0.2460

From Table 3.12a it can be noted that no positive correlation (> 0.80) is present between the distances obtained in the second aim (b) and the breadth of the fingers on the right hand of each cadaver. The distance between the supraorbital nerve and the midline correlates well with the medial three fingers, with a Pearson correlation coefficient of 0.73. However, this is below the chosen threshold of 0.80 for this research study.

Table 3.12b: Pearson correlation coefficient values for Group 1 with regard to the infraorbital measurements

	4 fingers	**3 fingers**	**2 fingers**	**1 finger**	**Thumb**
IO – Orbit (R-value)	**0.68**	0.60	0.55	0.52	0.57
p-value	<.0001	<.0001	0.0002	0.0005	0.0001
IO – M (R-value)	0.81	**0.85**	0.82	0.71	0.38
p-value	<.0001	<.0001	<.0001	<.0001	0.0143

From Table 3.12b it can be observed that a positive Pearson correlation coefficient of 0.85, which is statistically significant ($p < 0.05$), exists between the distance of the infraorbital nerves to the midline, and the breadth of the medial three fingers of the right hand of each cadaver.

3.4.3.2 The periorbital nerve blocks in infants

To ensure that the most effective method for blocking the periorbital nerves in infant patients are established, the distances obtained in the first and second aims, i.e. the distances between the “ideal” osteological values and the “real” cadaveric values, were compared for Group 2 (Figure 3.5).

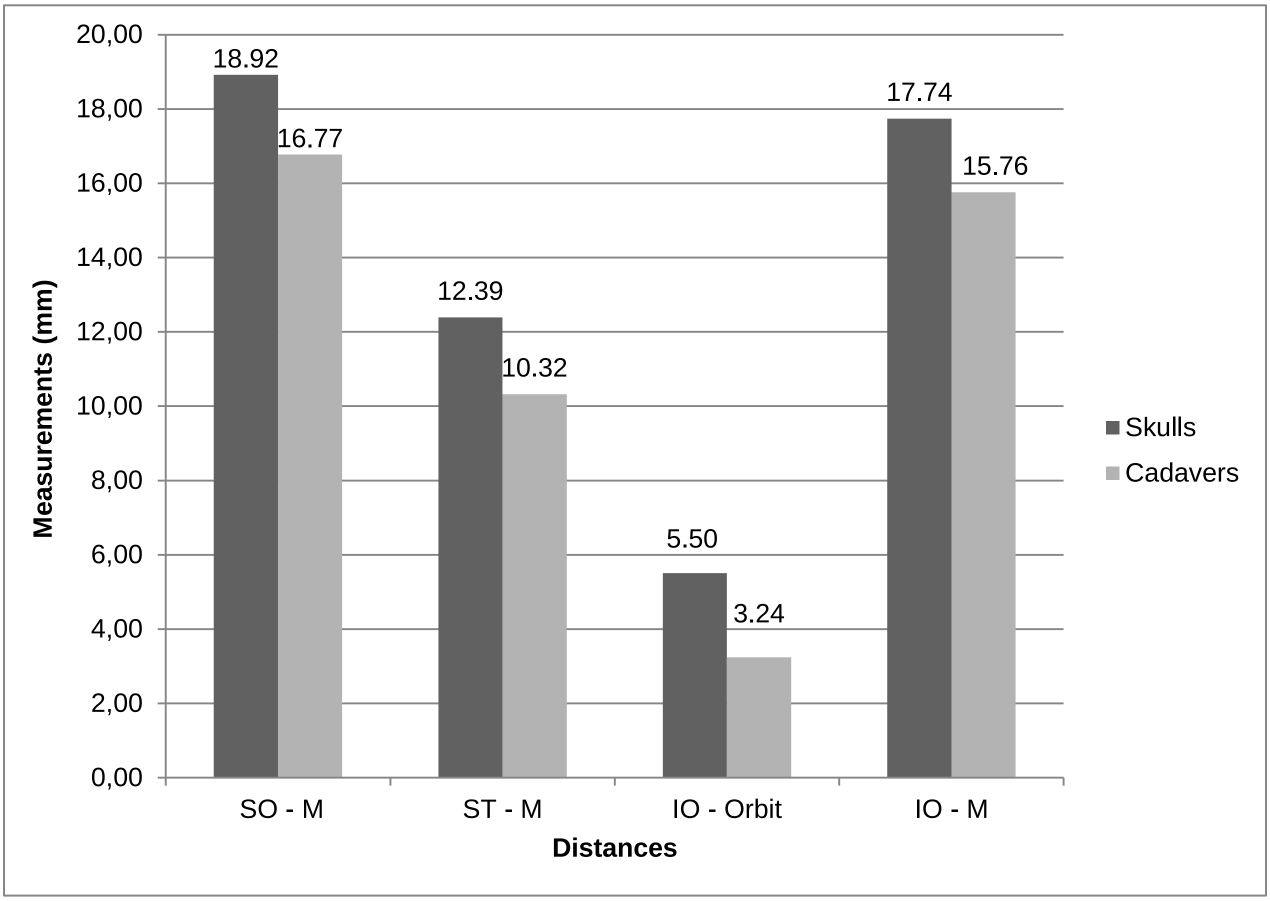


Figure 3.5: Direct comparison of measurements obtained from infant (Group 2) skulls and cadavers

[SO: Supraorbital nerve; M: Midline; ST: Supratrochlear nerve; IO: Infraorbital nerve]

When Figure 3.5 is viewed, a clear discrepancy of approximately 2mm per measurement is observed between the distances obtained from the cadaveric specimens and the corresponding distances obtained from the osteological specimens. However, a Kruskal-Wallis rank-based non-parametric comparison was used to determine whether a statistically significant difference ($p < 0.05$) was present between these two sample groups. The p-values for this test are presented in Table 3.13.

Table 3.13: p-values for non-parametric Kruskal-Wallis comparison between the skulls and cadavers of Group 2

	Distance SO - M	**Distance ST - M**	**Distance IO - Orbit**	**Distance IO - M**
p-value	0.088	0.0019	<0.0001	0.0056

Key:

SO: Supraorbital nerve
M: Midline
ST: Supratrochlear nerve
IO: Infraorbital nerve

The only measurement that displayed no statistically significant difference ($p > 0.05$) between the "ideal" osteological measurements and the "real" cadaveric measurements is the distance between the supraorbital foramen and the midline, and this by a very small margin. Therefore, it can be argued that the two sets of samples differ too greatly, and can thus not be combined to form a total sample for Group 2. Accordingly, only the "real" cadaveric distances were used for the infant population.

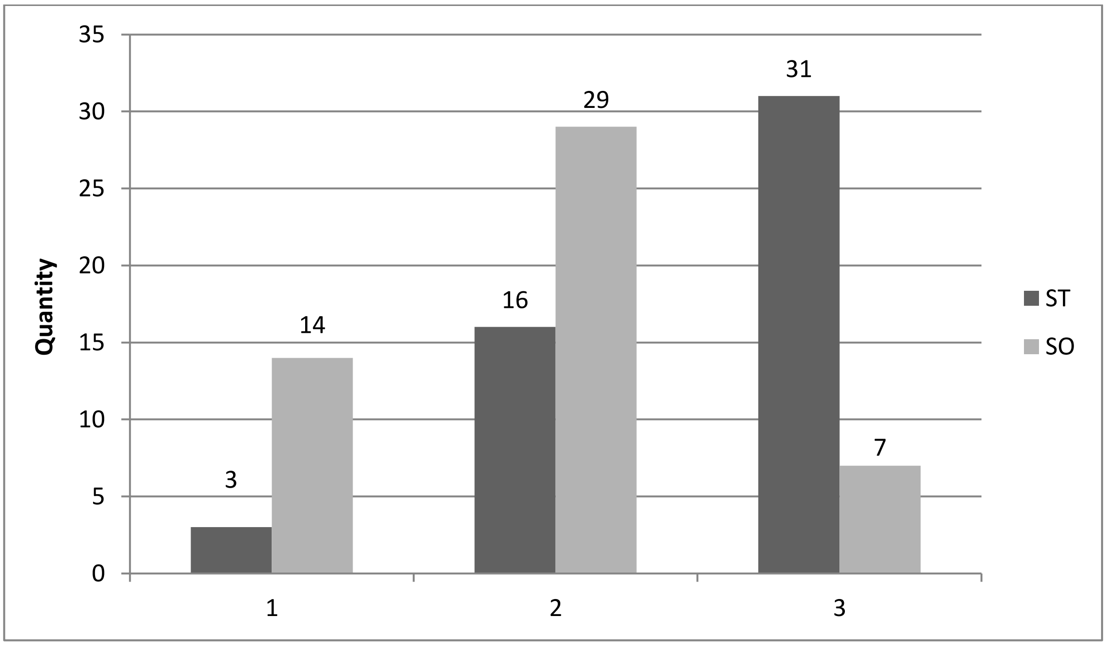


Figure 3.6: Direct comparison of periorbital bony landmark observations for the combined infant (Group 2) sample

[1: Periorbital foramen; 2: Periorbital notch; 3: No distinct osteological feature; ST: Supratrochlear nerve; SO: Supraorbital nerve]

If the two population groups are combined for the bony landmark observations, it can be observed from Figure 3.6 that, similar to the neonatal sample, no distinct osteological features were seen in 62% of the cases for the supratrochlear opening, while the supraorbital opening was identified as a notch in 58% of the samples.

The average measurements with regard to the fingers on the right hand of each infant cadaver are displayed in Table 3.14

Table 3.14: Average breadth of the fingers on the right hand for Group 2

	4 fingers	**3 fingers**	**2 fingers**	**1 finger**	**Thumb**
n	7	7	7	7	7
Mean	31.45	23.99	15.69	7.23	8.61
SD	6.84	5.85	4.24	1.63	2.11
CI95%	5.07	4.33	3.14	1.21	1.56
Lower	26.39	19.66	12.55	6.02	7.05
Upper	36.52	28.33	18.83	8.44	10.18

Key:

CI95%: Confidence interval of 95%
Lower: Lower range of values with a 95% confidence interval
Upper: Upper range of values with a 95% confidence interval

Only seven cadavers' fingers breadth could be measured, due to the upper limbs of two cadaveric specimens being disarticulated at the glenohumeral joints.

To assist with the development of more effective and easily performed periorbital nerve blocks, the distances obtained in the second aim were compared to the distances displayed in Table 3.14 by means of Pearson population correlations coefficients, in order to evaluate the relationship between the two sets of variables. These correlation coefficients for the infant cadavers of Group 2 are displayed in Table 3.15a and b.

Table 3.15a: Pearson correlation coefficient values for Group 2 with regard to the supraorbital and supratrochlear measurements

	4 fingers	**3 fingers**	**2 fingers**	**1 finger**	**Thumb**
SO – M (R-value)	0.84	**0.86**	0.79	0.74	0.83
p-value	0.0180	0.0120	0.0338	0.0572	0.0223
ST - M (R-value)	0.79	0.78	0.70	0.65	**0.82**
p-value	0.0357	0.0379	0.0787	0.1128	0.0252

As seen in Table 3.15a, a positive Pearson correlation coefficient of 0.86 is found between the distance of the supraorbital bony landmark to the midline and that of the breadth of the medial three fingers. A p-value of 0.0120 is observed, resulting in these distances being statistically significant ($p < 0.05$). Similarly, the breadth of the thumb correlates positively (0.82) to the distance between the supratrochlear landmark and the midline, with a statistically significant p-value of 0.0252.

Table 3.15b: Pearson correlation coefficient values for Group 2 with regard to the infraorbital measurements

	4 fingers	**3 fingers**	**2 fingers**	**1 finger**	**Thumb**
IO - Orbit (R-value)	0.80	0.74	0.73	0.71	**0.85**
p-value	0.0313	0.0557	0.0599	0.0736	0.0151
IO - M (R-value)	0.94	**0.95**	0.80	0.79	0.93
p-value	0.0013	0.0018	0.0290	0.0391	0.0002

When the values presented in Table 3.15b are analysed, a positive Pearson correlation coefficient of 0.85 is observed between the distance from the inferior orbital margin to the infraorbital foramen, with a statistically significant p-value of 0.0151. The highest Pearson correlation coefficient (0.95) is present between the breadth of the medial three fingers and the distance between the infraorbital foramen and the midline. This relationship also displays a statistically significant difference ($p < 0.05$) and can therefore be utilised in the development of the technique to block the infraorbital nerve as it emerges from the infraorbital foramen.

3.5 Discussion

The trigeminal nerve is the main general sensory nerve for the head, which includes the face, teeth, mouth and nasal cavities (Moore and Dalley, 2006). Since the supratrochlear, supraorbital and infraorbital nerves (periorbital nerves) are cutaneous terminal branches of the first and second divisions of the trigeminal nerve (Standring, 2008), it is understandable that the main indication for blocking these nerves is to anaesthetise the skin of the head. Should surgical anaesthesia of the face or treatment of painful facial conditions be required, periorbital nerves blocks can be utilised (Silver, 2015).

The supraorbital and supratrochlear nerve blocks are mostly indicated for surgeries of the superior eyelid and forehead (Suresh and Voronov, 2006; Pulcini and Guerin, 2007), while the infraorbital nerve block is most commonly performed on paediatric patients during cleft lip repair (Bosenberg and Kimble, 1995; Bosenberg, 1999; Suresh and Voronov, 2006; Suresh *et al.,* 2006; Belvis *et al.,* 2007; Jonnavithula *et al.,* 2007; Rajamani, 2007; Kim, 2009; Prabhu *et al.,* 2009).

The supratrochlear and supraorbital nerves emerge onto the scalp in relation to the superior orbital margin (Suresh and Wagner, 2001; Salam, 2004), albeit through a foramen (Pulcini and Guerin, 2007; Osborn and Sebeo, 2010) or a notch (Suresh and Voronov, 2006). The infraorbital foramen is often described as being located in line with the centre of the pupil (Bosenberg, 1999; McAdam *et al.,* 2005; Peltier, 2006; Suresh *et al.,* 2006; Belvis *et al.,* 2007; Voronov and Suresh, 2008; Kim, 2009; Wells, 2010), even though several additional descriptions are provided.

Although several techniques are explained in the literature, the general consensus is that the periorbital nerves should be anaesthetised as they emerge onto the scalp from their respective bony landmarks. Bosenberg (1999), Suresh and Voronov (2006) and Kim (2009) described a single injection technique to block the supraorbital and supratrochlear nerves in a paediatric population. On the other hand, Salam (2004) and Young and co-workers (2008) described a multi-injection technique.

In order to block the infraorbital nerve at the infraorbital foramen, several transcutaneous approaches are described in the literature. Bosenberg and Kimble (1995) use an injection point approximately midway along a line drawn from the middle of the palpebral fissure to the angle of the mouth, while Voronov and Suresh (2008), as well as Eipe and co-authors (2006), palpate the floor of the orbital rim in order to locate the infraorbital foramen.

Although several techniques on blocking the periorbital nerves have been discussed in the literature, no standardised descriptions of the technique of blocking these nerves exist for a paediatric population, especially ones based on paediatric anatomical cadaveric dissections.

3.5.1 Measurements for periorbital nerves on osteological specimens

In order to determine an easy technique for blocking the periorbital nerves in the paediatric population, osteological specimens were evaluated in order to obtain the most ideal values, based on no soft tissue obscuring any possible measurements or observations.

3.5.1.1 Measurements for neonatal skulls

In Table 3.1 the measurements obtained from nine neonatal skulls are presented. These skulls form part of Group 1, where the specimens are aged between 0 – 28 days after birth. From this table it can be noted that the supraorbital bony landmark is approximately 13.85mm (range: 12.57mm – 15.12mm) lateral to the midline, while the supratrochlear bony landmark is 8.86mm (range: 8.19mm – 9.54mm) from the midline. In close relation, the infraorbital foramen is located 13.41mm (range: 12.35mm – 14.47mm) lateral to the midline and 3.47mm (range: 2.94mm – 4.00mm) inferior to the inferior orbital rim.

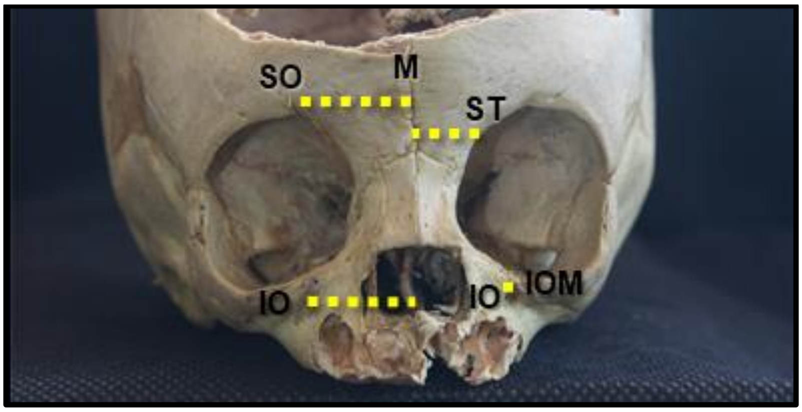


Figure 3.7: Anterior view of a neonatal skull indicating distances measured for periorbital bony landmarks

[SO – Supraorbital bony landmark; M – Midline; ST – Supratrochlear bony landmark; IO – Infraorbital foramen; IOM – Inferior orbital margin]

It is clear from Figure 3.7 and Table 3.1 that the distances between the supraorbital bony landmark and midline, as well as the infraorbital bony landmark to the midline, are similar, being 13.85mm and 13.41mm, respectively. As indicated by Suresh and Voronov (2006), Voronov and Suresh (2008) and Kim (2009), both the supraorbital and infraorbital foramina are located in line with the pupil, suggesting that these two bony landmarks are found in the same vertical plane. This is confirmed by Chrcanovic and co-workers (2011) who state that the infraorbital foramen is located in the same vertical plane as the supraorbital foramen in 52.5% of their sample.

Agthong and co-workers (2009) make the following statement: “Neurovascular bundles of the supraorbital, infraorbital, and mental foramina are important structures that need to be considered in local anaesthesia and surgical procedures in the maxillofacial area. An understanding of the anatomy of the location of these foramina is essential for performing effective nerve block and avoiding injuries to the neurovascular bundles.” Based on statements such as the aforementioned, the openings through which the supraorbital and supratrochlear nerves emerge onto the forehead were evaluated and are presented in Table 3.2.

When evaluating the supratrochlear bony landmark, the presence of a supratrochlear notch was observed in 44.4% (8/18) of the cases, while the remaining ten skulls (55.6%) displayed no specific osteological feature. This is consistent with the statement made by Standring (2008) that the supratrochlear neurovascular bundle emerges from a small frontal notch, medial to the supraorbital foramen in 50% of cases.

Regarding the supraorbital bony landmark, a notch was present in 11 (61.1%) of the 18 skulls examined, while the remaining seven skulls (38.9%) exhibited no specific osteological feature. Chrcanovic and colleagues (2011) established that in 47.5% of the cases, the supraorbital bony landmark was a notch. They referenced six articles in which a higher incidence of a supraorbital foramen was present, ranging from 69.9% - 92.5%.

3.5.1.2 Measurements for infant skulls

Sixteen osteological specimens ranging from 28 days to one year after birth were evaluated as part of the Group 2 infant sample. The distances obtained between the periorbital bony landmarks are presented in Table 3.3 and subsequently illustrated in Figure 3.8 below.

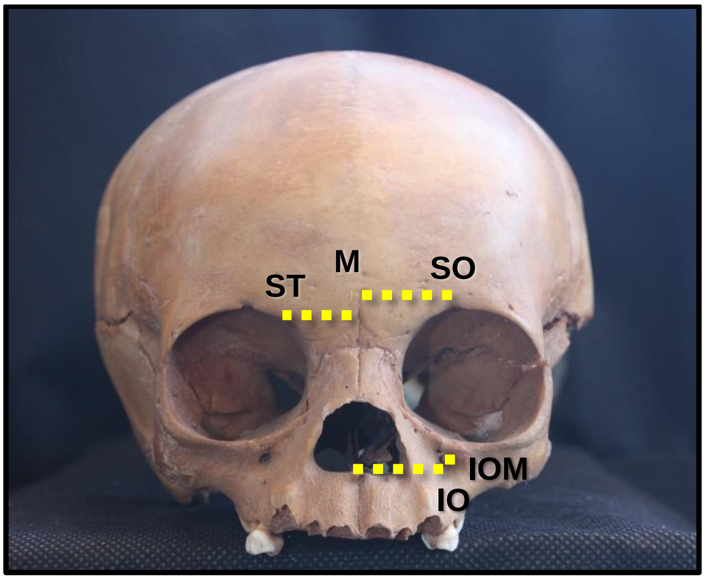


Figure 3.8: Anterior view of an infant skull indicating distances measured for periorbital bony landmarks

[SO – Supraorbital bony landmark; M – Midline; ST – Supratrochlear bony landmark; IO – Infraorbital foramen; IOM – Inferior orbital margin]

The supraorbital bony landmark is on average 18.92mm (range: 18.25mm – 19.59mm) from the midline, while the supratrochlear bony landmark is located 12.39 mm (range: 11.94mm – 12.84mm) lateral to the midline. The infraorbital foramen is located 17.74mm (range: 17.23mm – 18.25mm) from the midline and 5.50mm (range: 5.19mm – 5.82mm) below the inferior orbital margin.

The distances between the supraorbital bony landmark and the midline (18.92mm), and the infraorbital bony landmark and midline (17.74mm) are, as in the neonatal sample, very similar. Therefore, it can be argued that these bony landmarks are located in the same vertical plane.

Suresh and Voronov (2006) indicate that the location of the infraorbital foramen is approximately 25mm from the midline, at the floor of the inferior orbital rim. In a different study conducted by Suresh and co-workers (2006), CT guided images were used to determine that the infraorbital foramen is 21.3mm + 0.5 x age (in years) from the midline, and states that the age of the patient accounted for more than 50% of the variation observed in their model. If the equation of Suresh *et al.* (2006) is applied to the osteological specimens of this research study (Group 2), the infraorbital foramen is located 21.3mm from the midline when the age in years is considered zero. Therefore, the value obtained from the equation (21.3mm) and the distance measured in this research study (17.74mm), differs with 3.56mm. Although a discrepancy is present, these values are still comparable.

Bhargava and co-workers (2011) referenced a study conducted by Scarfe and co-workers in 1998 where panoramic radiographs of the infraorbital canal were evaluated. They conclude that the infraorbital foramen is located approximately 5 - 8mm inferior to the midpoint of the inferior orbital rim. This is in accordance with a study by Chrcanovic *et al.* (2011), where they indicate that the infraorbital foramen is located 6.5mm below the inferior orbital margin. Even though both of the abovementioned studies were conducted on adult specimens, it closely relates to the measurement of 5.50mm (range: 5.19mm – 5.82mm) that was obtained for the infant sample.

During the determination of the exact type of bony landmark at the location of the emergence of the supraorbital and supratrochlear neurovascular bundles, it can be seen from Table 3.4 that a similar pattern emerges as seen in the neonatal group. Figure 3.9 displays the presence of a supraorbital foramen on the right side of a paediatric skull, and supraorbital notch on the left side of the same skull.

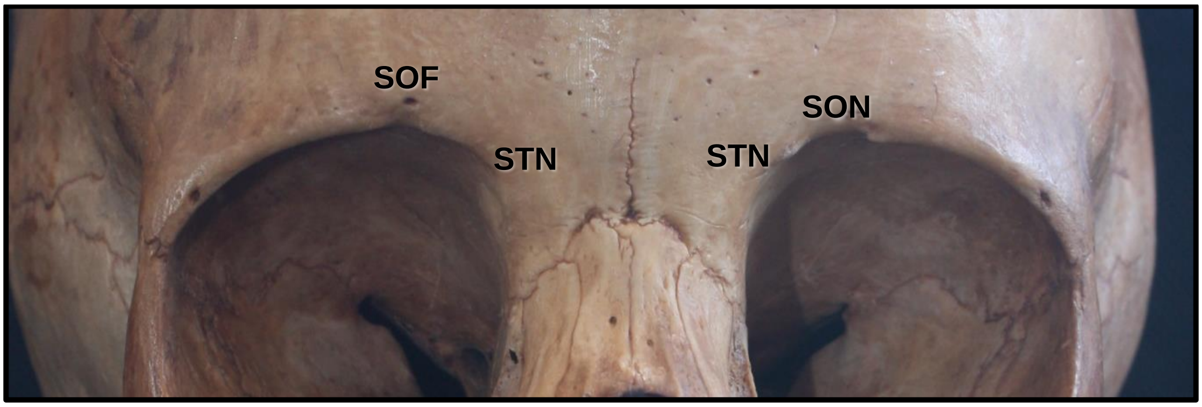


Figure 3.9: Enlarged anterior view of paediatric skull to illustrate different periorbital bony landmarks observed on one specimen

[SOF – Supraorbital foramen; STN – Supratrochlear notch; SON – Supraorbital notch]

A unilateral supratrochlear foramen was observed in only one (3.1%) skull. In 43.8% (14/32) of the specimens, a supratrochlear notch was identified, while no specific osteological feature was observed in 53.1% (17/32) of the specimens. With regard to the supraorbital bony landmark, a foramen was present in 6.3% (2/32) of the skulls, while 78.1% (25/32) of the specimens exhibited a supraorbital notch and there were no specific osteological feature present in 15.6% (5/32) of the cases.

Turhan-Haktanir and co-workers (2008) evaluated the variations of the supraorbital foramina in living subjects by means of multidetector computed tomography. They concluded that the supraorbital foramen was absent in 11.5% and 12.5% of their samples on the left and right sides, respectively. A single foramen was observed in 12.4% of the patients on the right side and 14.5% on the left, while a single supraorbital notch was observed on the right side in 69.4%, and on the left side in 68.2% of the cases. A double notch or foramen was present in 6.9% of the cases on the right side and 4.8% on the left side. Their values on the absent bony landmark are similar to the 15.6% observed in this research study, with the majority of our specimens exhibiting a supraorbital notch (78.1%). Differences in observed values can be attributed to their larger sample size of 399 patients, as well as the age of the patients. Regardless, it can be postulated that a higher frequency of supraorbital notches than foramina are observed in these studies.

Our findings can be linked to the statement made by Tomaszewska and co-workers (2012): “The supraorbital vein, which is more exposed and more prone to heat loss when it passes through supraorbital notch than through supraorbital foramen as well as smaller frontal sinuses in populations from colder regions may have also played a role in determining the type of the supraorbital structure in populations from different climatic conditions”.

3.5.2 Measurements for periorbital nerves on cadaveric specimens

In order to develop an effective technique of blocking the periorbital nerves, observations and measurements were collected based on anatomical dissections on a paediatric specimen population. These “real” values will assist in the development of an easily performed technique of blocking the periorbital nerves in the paediatric population.

3.5.2.1 Neonatal specimens

The periorbital nerves were dissected bilaterally in 41 neonatal cadavers (Group 1) and the measurements are displayed in Table 3.5. From the measurements obtained, as illustrated in Figure 3.10a and b, the supraorbital nerve can be found 13.57mm (range: 12.80mm – 14.34mm) lateral to the midline, while the supratrochlear nerve is observed 8.21mm (range: 7.70mm – 8.71mm) from the midline. The infraorbital foramen is located at a point 2.88mm (range: 2.69mm – 3.07mm) below the inferior orbital rim and 12.78mm (range: 12.16mm – 13.41mm) from the midline.

a) *b)*

Figure 3.10a: Anterior view of left supraorbital region indicating distances measured below an inferiorly reflected skin flap;

b: Anterior view of the right infraorbital region indicating distances measured [M – Midline; ST – Supratrochlear nerve; SO – Supraorbital nerve; IOM – Inferior orbital margin; IO – Infraorbital foramen]

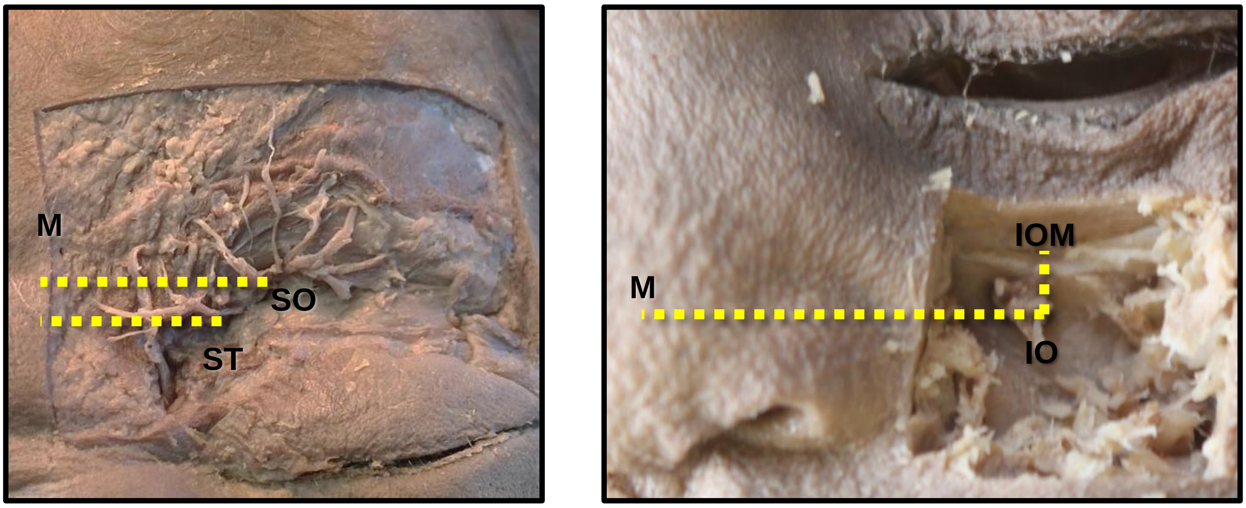
In a study conducted by Bosenberg and Kimble (2015), the infraorbital nerve block was evaluated in 15 neonatal cadavers. They concluded that the infraorbital nerve is located halfway on a line extending from the middle of the palpebral fissure to the angle of the mouth, approximately 7.5mm from the alar base. Even though no direct comparison can be made between their study and this research study due to different measuring landmarks used, the importance of neonatal research with regard to the impracticality of using landmarks described for adults, is invaluable.

The specific bony landmarks from which the supraorbital and supratrochlear nerves emerge as obtained by dissections, are noted in Table 3.6. From these observations it can be seen that in 90.2% (74/82) of the dissections, the supratrochlear nerve emerges from a bony landmark with no distinct osteological features. For the remaining specimens 7.3% (6/82) and 2.4% (2/82) emerged from either a foramen or a notch, respectively. This is in contrast with the statement made by Suresh and Voronov (2006) that, in most skulls (97%), bilateral supratrochlear notches are observed, with 1% exhibiting unilateral foramina and 2% displaying a notch on the one side and a foramen on the other. These differences can be due to the presence of soft tissue in this research study, which obscures the ability of identifying a supratrochlear notch.

The majority of supraorbital nerves 47.6% (39/82) emerged from a foramen, while 23.2% (19/82) emerged through a notch and 29.3% (24/82) emerged from a bony landmark with no distinct osteological features (Table 3.6). Gupta (2008) found a similar distribution when evaluating adult skulls, with regard to the 45.6% incidence of supraorbital foramina. However, the remainder of that sample (54.4%) displayed supraorbital notches.

3.5.2.2 Infant specimens

As part of the paediatric population of cadavers dissected, Group 2 included nine infant cadavers from 28 days to one year after birth. Measurements obtained from these dissections are displayed in Table 3.7 and illustrated in Figure 3.11a and b.



a) *b)*

Figure 3.11a: Anterior view of the left supraorbital region indicating distances measured for an infant cadaver;

b: Anterior view of the left infraorbital region indicating distances measured

[M – Midline; ST – Supratrochlear nerve; SO – Supraorbital nerve]

The supraorbital nerve emerges, on average, 16.77mm (range: 15.29mm – 18.25mm) from the midline at the superior orbital margin, while the supratrochlear nerve is situated 10.32mm (range: 9.11mm – 11.53mm) from the midline. Even though this research study did not measure the exact distance between these two nerves, it can be reasoned from the measurements, that they are, on average, 6.45mm apart. This compares well to the description of Voronov and Suresh (2008) indicating that the supraorbital nerve is anaesthetised based on the palpation of the supraorbital notch. However, the needle is then directed medially and advanced 5mm in order to block the supratrochlear nerve.

The infraorbital nerve is located 15.76mm (range: 14.44mm - 17.17mm) from the midline and 3.24mm (range: 2.85mm – 3.63mm) inferior to the inferior orbital rim, for this sample of infant cadavers. Belvis and co-workers (2007) indicate that the infraorbital nerve is located 25mm lateral to the midline at the floor of the inferior orbital rim. The discrepancy with regard to the distance from the midline to the infraorbital foramen can be attributed to the age of the patients involved, since this result was obtained from infant cadavers, while their population sample had a mean age of 9.7 years, ranging from 0.8 to 17.75 years.

In the study by Lee and authors (2012), the distance between the inferior orbital margin and the infraorbital foramen was determined at 6.78mm, for their sample group of 30 patients ranging between 0 – 9 years of age. In a recent study conducted by Ercikti and co-workers (2017), the location of the infraorbital nerve with reference to soft tissue landmarks, was evaluated. They concluded that the infraorbital nerve is located, on average, 8.8mm below the inferior orbital rim and 30.3mm from the midline of the face. Even though this study was conducted on adults cadavers, it emphasizes the statement made by Lee *et al.* (2012) that the position of the infraorbital foramen showed rapid change during the first three years of life.

When the bony landmarks of the superior orbital margin are evaluated (Table 3.8), it can be noted that the supratrochlear nerve emerges from a bony landmark with no distinct osteological features in 77.8% (14/18) of the cases, while equal quantities of 11.1% (2/18) each of notches and foramina were observed. This is in contrast to the high number of supratrochlear notches (97%) reported by Suresh and

Voronov (2006). It can be noted that due to soft tissue still being present, the exact shape and category of the supratrochlear bony landmark might be concealed.

The supraorbital nerve emerged from a foramen in 66.7% (12/18) of the cases, a notch in 22.2% (4/18), and a smooth supraorbital ridge in 11.1% (2/18) of the specimens (Table 3.8). This is a slightly higher value than reported by Sheikh *et al.* (2014) who found that their Egyptian adult skulls displayed a supraorbital notch in 50.8% of the sample and a supraorbital foramen in 38.97% of the evaluated skulls. However, in their study, they had a third category for a supraorbital ridge, which is an incomplete foramen but with sharp edges. Differences between categories evaluated, as well as the presence of soft tissue, can result in different osteological features observed.

3.5.3 Periorbital nerve blocks in paediatric patients

Gupta (2008) makes the following very important statement: “Effective and precise analgesia can be achieved only if one is aware of the most frequent location of exit of the nerves of this region”. This statement is obtained from his research study on the important facial foramina, and emphasises the need for anatomical studies and the importance of anatomical knowledge.

Very few results could be obtained from the literature on research on the origin of paediatric specific standards used in a clinical setting. Several authors such as Suresh and Voronov (2006), Belvis *et al.* (2007), Voronov and Suresh (2008), Kim (2009) and Suresh and Voronov (2012), make use of palpation of the periorbital bony landmarks in order to locate the periorbital nerve block. However, Michalek and co-workers (2013) state that palpation of the infraorbital foramen is not always possible especially if patients present with facial tumours, facial oedema or surgery to the maxilla.

In accordance with the previous statement, Suresh *et al.* (2006) state: “Although clinical measures are usually used to locate the foramen, including the palpation of the infraorbital notch and the correlation of the infraorbital foramen to the location of the midpoint of the pupil, locating the infraorbital foramen by clinical examination alone may sometimes be difficult.” Therefore, anatomical studies based on measurements obtained from population specific sample groups are required to assist in the executing of paediatric regional nerve blocks.

3.5.3.1 The periorbital nerve blocks in neonates

In order to establish the most effective method for blocking the periorbital nerves in the paediatric population, the distances obtained from the osteological specimens, the “ideal” values and the “real” values obtained from the cadaveric specimens need to be compared.

In Figure 3.3, a direct comparison is made by means of a bar graph. The values obtained appear comparable. However, a Kruskal-Wallis non-parametric ranked test was performed to provide statistical basis for this assumption and the obtained p-values are presented in Table 3.9.

From the comparisons between the values obtained from the skull samples and the cadaver samples, no statistically significant difference ($p > 0.05$) was observed for the distances between the supraorbital nerve to the midline, supratrochlear nerve to the midline or the distance between the inferior orbital margin to the infraorbital foramen. Therefore, these two sample datasets can be combined (for these specific measurements) to obtain a complete periorbital dataset.

However, the distances between the infraorbital foramen / nerve and the midline exhibited a p-value of 0.0264. This confirms a statistically significant difference between the osteological and cadaveric measurements. The two samples can therefore not be combined. This difference can be attributed to the presence of soft tissue, which obscures accurate osteological assessment in the cadaveric specimens as observed in a study conducted by Hwang *et al.* (2004). Their study concludes that the infraorbital nerve has 19.5 terminal branches, arising from the three branches of the infraorbital nerve. Therefore, some of these branches exiting the infraorbital foramen can make exact pinpointing of the midpoint of the infraorbital foramen problematic.

For the neonates of Group 1, the supraorbital nerve traverses the supraorbital bony landmark, on average, 13.62mm (range: 12.95mm – 14.29mm) lateral to the midline, while the supratrochlear nerve is located 8.33mm (range: 7.89mm – 8.76mm) from the midline of the face (Table 3.10). As previously stated, authors such as Belvis *et al.* (2007), Voronov and Suresh (2008), Kim (2009), Suresh and Voronov (2012), who block the supraorbital and supratrochlear nerves in paediatric patients, locate the supraorbital foramen by means of using the mid-pupillary line. Suresh and Wagner (2001), Suresh and Voronov (2006), as well as Serra-Guillen and co-workers (2009), then state that the needle is directed and advanced medially in order to anaesthetise the supratrochlear nerve. However, no distance for this advancement is indicated.

Voronov and Suresh (2008) indicate during the description of their technique that the needle is withdrawn and then directed 5mm medially. Even though the exact distance between the supraorbital and supratrochlear nerves was not measured, the difference between the distances of these two nerves (13.62mm and 8.33mm) is 5.29mm. Therefore, it can be assumed that the results of this study correlate well with the statement made by Voronov and Suresh (2008) that the needle should be directed 5mm medially from the supraorbital nerve.

The infraorbital nerve is located 2.99mm (range: 2.80mm – 3.18mm) below the inferior orbital margin, based on the results of the total sample summarised in Table 3.10. In Table 3.5 it can be seen that the infraorbital nerve emerges 12.78mm (range: 12.16mm – 13.41mm) lateral to the midline of the face. Bosenberg and Kimble (1995) determined the bilateral location of the infraorbital foramen in 15 neonatal cadavers and concluded that the infraorbital nerve is located halfway on the line between the midpoint of the palpebral fissure and the angle of the mouth, approximately 7.5mm from the alar base. Rajamani *et al.* (2007) also used the previous technique to evaluate the efficacy of the infraorbital nerve block in patients undergoing cleft lip repairs. Even though the results of this research study, and that of Bosenberg and Kimble (1995) cannot be directly compared due to different landmarks that were used, the importance of anatomical studies being performed on neonatal samples should continually be emphasised.

Zaizen and Sato (2013) referenced a statement made by Song *et al.* (2012) in their study, that stated: “Moreover, the morphological features of the infraorbital canal and accessory bony canals affect the course of the infraorbital nerve and artery supply”. This statement can also be applied to the supraorbital and supratrochlear bony landmarks. Therefore, the variations observed for these bony landmarks were evaluated and displayed in Figure 3.4.

In this research study, we observed that in 84% of the sample, the supratrochlear bony landmark displayed no distinct osteological feature, with 6% of the sample displaying a supratrochlear foramen and 10%, a supratrochlear notch. Therefore, no notch, foramen, fissure or any classified bony landmark was present, in the large majority of this sample. The passage of the supratrochlear neurovascular bundle did not leave any markings on the bone. This is in contrast with the following statement made by Suresh and Voronov (2006): “Most skulls (97%) possess bilateral supratrochlear notches; however, 1% possess unilateral foramina, and 2% have a notch on one side and a foramen on the other.” The discrepancies between the two studies can be based on population, gender or climate differences. Further investigation into these occurrences is thus warranted.

We found that the distribution of the relation of the supraorbital nerve to bony landmarks was almost equal between the categories, with 39% displaying a supraorbital foramen, 30% a supraorbital notch and 31% no distinct osteological feature. A study conducted by Tomaszewska *et al.* (2012) supports the hypothesis that supraorbital notches are more commonly found in populations from warmer regions, compared to those who live in colder climates. However, since the presence of soft tissue could result in the exact bony landmark identification being hindered in this research study, a more thorough investigation into these bony landmarks is required.

As described by Michalek and co-workers (2013), palpation of bony landmarks is not always possible. Therefore, an easier, more effective method to block the periorbital nerves in neonatal patients needs to be developed. To facilitate the development of such techniques, the breadth of the proximal interphalangeal joint on the right hand of each cadaver was measured and captured in Table 3.11 in order to correlate the breadth of the finger to the distances measured during the investigation of the periorbital nerves.

Using Pearson correlation coefficient determination, as seen in Table 3.12a and 3.12b, the only distance obtained for the periorbital nerve blocks that correlates above the 0.80 study threshold to the breadth of the fingers on the right hand of each cadaver, was the distance between the infraorbital nerve and the midline, and the medial three fingers. A correlation coefficient of 0.85, with a statistically significant p-value of less than 0.0001, was obtained. Therefore, in a clinical setting, the breadth of the interphalangeal joint of the medial three fingers can be used to determine the approximate distance of the infraorbital nerve from the midline.

To summarize the anatomical information obtained with regard to the periorbital nerves in the neonatal population (Group 1): The supraorbital nerve emerges 13.62mm lateral to the midline of the face, at the supraorbital foramen / notch. The supratrochlear nerve appears approximately 5mm medial to the supraorbital nerve, at a distance of 8.33mm from the midline of the face. The infraorbital nerve is located 2.99mm inferior to the orbital rim, 12.78mm lateral to the midline of the face. This distance corresponds with the average breadth of the proximal interphalangeal joints of the medial three fingers. Gupta (2008) states that the supraorbital and infraorbital nerves emerge in a narrow zone of high clinical importance with a width of approximately 1 cm extending from 2 – 3cm on each side of the midline of the face. Therefore, the supraorbital nerve can be palpated in a vertical plane, within a 10mm zone of the infraorbital nerve.

The following technique for blocking the periorbital nerves is proposed: In a neonatal population, the supraorbital notch / foramen can be palpated approximately 13.5mm from the midline, with the supratrochlear nerve located 5mm medial to that. The infraorbital nerve can be located just inferior to the inferior orbital margin (3mm), 13mm (three medial fingers’ breadth) from the midline of the face, almost in line with the vertical plane of the supraorbital nerve.

3.5.3.2 The periorbital nerve blocks in infants

With the purpose of finding the most effective method of blocking the periorbital nerves in infant patients, distances and observations were obtained from both osteological and cadaveric specimens. Through the comparison of the “ideal” osteological values and the “real” cadaveric values (Figure 3.5), clear descriptions of the periorbital nerves could be formulated.

Following the graphic representation of this comparison in Figure 3.5, Table 3.13 displays the p-values of the subsequent Kruskal-Wallis non-parametric rank-based test. The only distance that exhibited no statistically significant difference ($p > 0.05$) between the osteological and cadaveric measurements was that of the supraorbital nerve to the midline of the face. A p-value of 0.088 was obtained, which, in the context of the remaining measurements, is considered too small a margin, resulting in these two samples not being comparable. This can be linked to the relatively small sample size for the population groups that were evaluated (16 infant skulls and nine infant cadavers), resulting in an inability to accurately compare the samples.

When the bony landmark observations displayed in Figure 3.6 are assessed, it can be noted that, similar to the neonatal sample, the supratrochlear nerve is not related to a distinct osteological feature as it curves around the supraorbital margin in 62% of the sample. A supratrochlear foramen was identified in 6% of the sample group, while 32% of the specimens exhibited a supratrochlear notch. This is in contrast to Standring (2008) who reports that the supratrochlear nerve emerges from a frontal notch / foramen that lies medial to supraorbital notch. This frontal notch is observed in 50% of skulls between the trochlea and the supraorbital notch.

In this research study, the supraorbital bony landmark presented as a notch in 58% of the specimens, a foramen in 28% of the specimens and no distinct osteological feature could be identified in 14% of the samples. This is in contrast to the statements made by Chrcanovic and co-authors who referenced several studies where a higher incidence of foramina than notches was observed. In their specific study they observed that 47.5% of their sample displayed supraorbital notches, while

52.5% of the sample exhibited supraorbital foramina. However, this research study exhibited a greater percentage of supraorbital notches than foramina. This could be attributed to the relatively small sample size used in this research study, as well as the presence of soft tissue, that could limit clear observation of the bony landmarks.

In order to develop an easier technique of blocking the periorbital nerves in the infant population, the proximal interphalangeal breadth of the right hand of each cadaver is displayed in Table 3.14, with the Pearson population correlation coefficients and the subsequent p-values being represented in Table 3.15a and 3.15b.

In Table 3.15a, a positive Pearson correlation coefficient of 0.86 with a p-value of 0.0120 can be observed between the distance from the supraorbital bony landmark to the midline, and the breadth of the medial three fingers. Therefore, since the Pearson coefficient is greater than this research study's 0.80 threshold, and it exhibits a statistically significant p-value of smaller than 0.05, it can be argued that, in a clinical setting, the medial three fingers' breadth can be used to indicate the distance between the supraorbital bony landmark and the midline.

Similarly, the breadth of the interphalangeal joint of the thumb exhibits a positive correlation (0.82) to the distance between the supratrochlear bony landmark and the midline of the face. A statistically significant difference of 0.0252 was determined, indicating that these two distances are similar, with very little chance of affecting the outcome.

When the infraorbital foramen and the associated distances are evaluated and compared by means of a Pearson population correlation coefficient test, a positive correlation between the distance from the inferior orbital margin to infraorbital foramen, and the breadth of the interphalangeal joint of the thumb is observed. This correlation proves statistically significant with a p-value of 0.0151. Thus, the thumb can be used to determine the location of the infraorbital foramen below the orbit.

The highest Pearson correlation coefficient observed in Table 3.15b, is a value of 0.95. This positive correlation is observed between the distance of the infraorbital nerve to the midline, and the breadth of the medial three fingers. A statistically significant p-value of 0.0018 is noticed. Therefore, the medial three fingers can be used in a clinical setting to determine the location of the infraorbital foramen from the midline of the face.

In summary, the following anatomical descriptions and measurements were obtained during the dissections of the periorbital area in infants (Group 2): The supraorbital nerve emerges from the supraorbital notch at an average distance of 16.77mm from the midline, while the supratrochlear nerve emerges 6.5mm medial to supraorbital nerve, approximately 10.32mm lateral to the midline. The infraorbital nerve is located 3.24mm below the inferior orbital rim and 15.76mm lateral to the midline of the face. The breadth of the thumb correlates well with both the distance of the supratrochlear nerve to the midline and the infraorbital nerve below the orbit. Similarly, the breadth of the medial three fingers correlates positively with the distances of the supraorbital and infraorbital nerves to the midline of the face.

The following technique for blocking the periorbital nerves in infants is proposed: The supraorbital notch can be palpated approximately 16.5mm from the midline, with the supratrochlear nerve located 6mm medial to that, one thumb breadth from the midline. The infraorbital nerve is located 15.8mm lateral to the midline, a thumbs breadth inferior to the orbit. The supraorbital and infraorbital nerves emerge in the same vertical plane, three medial fingers’ breadth from the midline.

3.6 Limitations of this study and proposed future research

The following limitations on this part of the research study were identified and are proposed for future research studies:

1. A more detailed description of the periorbital bony landmarks is required based on height and width of the respective landmarks, the presence of accessory openings and additional measurements to easily palpable bony landmarks such as the nasion and glabella. This will assist with determining the exact location of the periorbital neurovascular bundle for both regional anaesthetic techniques and surgical approaches to this region.

2. A more detailed description and evaluation of the relationship between the supraorbital~ and infraorbital bony landmarks are required for different age~ and population groups. This will facilitate better performance of regional anaesthetic techniques in all populations and age groups.

3. Supplementary observations on the exact relationships of the structures within the periorbital neurovascular bundle are required in the paediatric population. This will assist in minimising possible complications, such as haematoma formation.

4. The small infant cadaveric population, as well as osteological population, can be considered as a limitation. This is attributed to the scarceness of these types of samples. However, any anatomical information obtained from paediatric samples are considered priceless and will greatly aid the performance of regional anaesthetic nerve blocks in this exclusive population group.

3.7 Conclusion

The supraorbital and supratrochlear nerve blocks are predominantly used in paediatric patients for surgeries of the superior eyelid and forehead (Suresh and Voronov, 2006; Pulcini and Guerin, 2007), while the infraorbital nerve block is most commonly performed in paediatric patients during cleft lip repairs (Bosenberg, 1999; Suresh and Voronov, 2006; Kim, 2009; Prabhu *et al.,* 2009).

The supraorbital notch / foramen can be palpated approximately three (of the patient's) fingers' breadth from the midline of the face in the same vertical plane as the infraorbital foramen which is located 3mm below the orbit. The supratrochlear nerve is located 5 - 6mm medial to the supraorbital neurovascular bundle, approximately the same distance lateral to the midline of the face as the breadth of the patient's thumb.

This study hopes to support anaesthesiologists and clinicians to accurately and carefully administer periorbital nerve blocks in the paediatric population, based on the investigation of paediatric anatomical specimens.

3.8 References

Adam, OR; Jankovic, J. (2007) Treatment of dystonia. *Parkinsonism Relat Disord* 13(3): 362 – 368

Belvis, D; Voronov, P; Suresh, S. (2007) Head and neck blocks in children. *Tech Reg Anesth Pain Manag*, 11: 208 - 214

Bhargava, D; Sreekumar, K; Koneru, G; Deshpande, A. (2011) Anatomical basis for modified infraorbital orbitotomy. *J Stomat Occ Med* 4:115 – 117

Blumenfeld, A; Ashkenazi, A; Napchan, U; Bender, SD; Klein, BC; Berliner, R; Ailani, J; Schim, J; Friedman, DI; Charleston, L; Young, WB; Robertson, CE; Dodick, DW; Silberstein, SD' Robbins, MS. (2013) Expert consensus recommendations for the performance of peripheral nerve blocks for headaches – a narrative review. *Headache* 53: 437 – 446

Bosenberg, AT, (1999) Blocks of the face and neck, *Tech Regl Anesthesia Pain Manag* 3(3): 196 – 203

Bosenberg, AT; Kimble, FW. (1995) Infraorbital nerve block in neonates for cleft lip repair: Anatomical study and clinical application. *Br J Anaesth* 74: 506 – 508

Brennan, PA. (2009) Inferior dental nerve block complication. *Br Dent J* 54(3): 129 – 130

Byrne, KM. (2012) Infra-orbital nerve block. Medscape drugs disease and procedures. Cited from http://emedicine.medscape.com/article/82660-overview

Byrne, KM; Izzo, AJ. (2014) Supraorbital nerve block. Medscape drugs disease and procedures. Cited 23-11-2017 from https://emedicine.medscape.com/article/82641-overview#a1

Byrne, KM; Izzo, AJ. (2017) Infraorbital nerve block. Cited 8-12-2017 from https://emedicine.medscape.com/article/82660-overview#a3

Caputi, CA; Firetto, V. (1997) Therapeutic blockade of greater occipital and supraorbital nerves in migraine patients. *Headache* 37: 174 – 179

Chrcanovic, BR; Nogueir, MH; Abreu, G; Custodio, CAN. (2011) A morphometric analysis of supraorbital foramen and infraorbital foramina relative to surgical landmarks. *Surg Radiol Anat* 33: 329 – 335

Cohen, B; Silbiger, A; Otremski, S, Matot, I. (2011) Case scenario: metastatic pediatric paraganglioma presenting during the course of an elective surgery. *Anesth* 115: 408 – 413

Codner, MA; McCord, CD. (2016) Eyelid and periorbital surgery, 2nd edition. CRC press p 516

Dubash, BD; Hershkin, AT; Seider, PJ; Casey, GM. (2006) Oral and Maxillofacial regional anesthesia. The New York School of Regional Anesthesia. Cited from http://www.nysora.com/peripheral_nerve_blocks/head_and_neck_block/3062-oral_maxillofacial.com on 11/10/2012

Eipe, N; Choudhrie, A; Pillai, AD; Choudhrie, R. (2006) Regional anesthesia for cleft lip repair: a preliminary study. *Cleft Palate Craniofac J* 43: 138 – 141

Ercikti, N; Apaydin, N; Kirirci, Y. (2017) Location of the infraorbital foramen with reference to soft tissue landmarks. *Surg Radiol Anat* 39: 11 – 15

Evans, RW; Pareja, JA. (2009) Supraorbital neuralgia. *Headache* 49: 278 – 281

Gupta, T. (2008) Localization of important facial foramina encountered in maxilla-facial surgery. *Clin Anat* 21: 633 – 640

Hartley, EJ; Bissonnette, B; St-Louis, P; Rybczynski, J; McLeod, ME. (1991) Scalp infiltration with Bupivacaine in pediatric brain surgery. *Anesth Analg* 73: 29 – 32

Hwang, K; Suh, MS; Chung, IH. (2004) Special issue: Technical strategies, Cutaneous distribution of infraorbital nerve. *J Craniofac Surg* 15: 3 – 5

Hwang, SH; Kim, SW: Park, CS: Kim, SW: Cho, JH: Kang, JM. (2013) Morphometric analysis of the infraorbital groove, canal, and foramen on three-dimensional reconstruction of computed tomography scans. *Surg Radiol Anat* 35: 565 – 571

Jonnavithula, N; Durga, P, Kulkarni, DK; Ramachandran, G. (2007) Bilateral intra-oral, infra-orbital nerve block for postoperative analgesia following cleft lip repair in paediatric patients: comparison of bupivacaine vs, bupivacaine-pethidine combination. *Anaesthesia* 62: 581 – 585

Kim, S. (2009) Peripheral nerve blocks for children, New York school of regional anesthesia. Cited from http://www.nysora.com/regional_anesthesia/sub-specialties/pediatric_anesthesia/3086-peripheral_nerve_blocks_for_children

Lee, T; Lee, H, Baek, S. (2012) A three-dimensional computed tomographic measurement of the location of infraorbital foramen in East Asians. *J Craniofac Surg* 23: 1169 – 1173

Levin, M. (2009) Nerve blocks and nerve stimulation in headache disorders. *Tech Reg Anaesth Pain Manag* 13: 42 – 49

McAdam, D; Muro, K; Suresh, S. (2005) The use of infraorbital nerve block for postoperative pain control after transsphenoidal hypophysectomy. *Reg Anesth Pain Med* 30(6): 572 – 3

McDonald, JH. (2014) Handbook of Biological Statistics (3rd ed,). Sparky House Publishing, Baltimore, Maryland. p 126 – 130

Michalek, P; Donaldson, W; McAleavey, F; Johnston, P; Kiska, R. (2013) Ultrasound imaging of the infraorbital foramen and simulation of the ultrasound-guided infraorbital nerve block using a skull model. *Surg Radiol Anat* 35: 319 – 322

Moore, KL; Dalley, AF. (2006) Clinically orientated anatomy, 5th edition. Lippincott Williams and Wilkins. pg 48 – 51, 1139 – 1142

Osborn, I; Sebeo, J. (2010) Review article. “Scalp block” during craniotomy: a classic technique revisited. *Neurosurg Anesthesiol* 22(3): 187 – 194

Peltier, J. (2006) Regional anesthesia in head and neck surgery. Grand rounds presentation, UTMB, Department of Otolaryngology. Cited 10/10/2012 from http://www.utmb.edu/otoref/grnds/Local-anesthesia-of-the-head-neck-060524/regional-anaesthesia.com

Prabhu, KP; Wig, J; Grewal, S. (2009) Bilateral infraorbital nerve block is superior to peri-incisional infiltration for analgesia after repair of cleft lip. Scand *J Plast Reconstr Surg Hand Surg* 33: 83 – 87

Pulcini, A; Guerin, JP. (2007) Head and neck, Ophtalmic nerve blocks, Text taken from the European society of regional anaesthesia and pain therapy site. Cited from http://www.esra-learning.com/site/techniques/face/b_ophtalmic.htm on 20/09/2011

Rajamani, A; Kamat, V; Ponnambalam, R; Murthy, J; Hussain, SA. (2007) A comparison of bilateral infraorbital nerve block intravenous fentanyl for analgesia following cleft lip repair in children. *Paediatr Anaesth* 17:133 – 139

Salam, GA. (2004) Regional anesthesia for office procedures: Part I, Head and neck surgeries. *Am Fam Physician* 69: 585 – 590

Serra-Guillen, C; Hueso, L; Nagore, E; Vila, M; Llombart, B; Caballero, CR; Botella-Estrada, R; Sanmartin, O; Alfaro-Rubio, A; Guillen, S. (2009) Comparative study between cold air analgesia and supraorbital and supratrochlear nerve block for the management of pain during photodynamic therapy for actinic keratosis of the frontotemporal zone. *Br J Dermatol* 161: 353 – 356

Sheikh, EE; Nasr, WF; Ibrahim, AAS. (2014) Anatomical variations of supraorbital notch and foramen: a study on human adult Egyptian skulls. *Eur J Plast Surg* 37: 135 – 140

Silverman, S. (2015) Atlas of pain medicine procedures, 1st edition, Chapter 20: Periorbital nerve blocks (supraorbital, supratrochlear and infraorbital nerves). Editors: S Diwan and PS Staats, McGraw-Hill education

Standring, S. (2008) Gray's anatomy, 40th edition, The anatomical basis of clinical practice. Churchill, Livingstone, Elsevier, Chapter 29, p 470, 493 - 494

Suresh, S; Bellig, G. (2004) Regional anesthesia in a very low-birth-weight neonate for a neurosurgical procedure. *Reg Anesth Pain Med* 29: 58 – 59

Suresh, S; Voronov, P. (2006) Review article. Head and neck blocks in children: an anatomical and procedural review. *Ped Anesth* 16: 910 – 918

Suresh, S; Voronov, P. (2012) Review article. Head and neck blocks in infants, children, and adolescents. *Ped Anesth* 22: 81 – 87

Suresh, S; Voronov, P; Curran, J. (2006) Infraorbital nerve block in children: a computerized tomographic measurement of the location of the infraorbital foramen. *Reg Anest Pain Med* 31: 211 – 214

Suresh, S; Wagner, AM. (2001) Techniques for tots, Scalp excisions: getting "ahead" of pain. *Pediatr Dermatol* 18(1): 74 – 76

Tay, E; Gupta, M; Franks, W. (2006) Supraorbital nerve blocks in trabeculectomy surgery: an observational case series. *Clin Exp Ophthalmol* 34: 637 – 639

Thomsen, TW; Setnik, GS. (2005) Regional nerve blocks, facial blocks. The multimedia procedure manual. Cited on the 20th September 2011 from http://emprocedures.com/nerveblocks/facial.htm or the following website as well, http://wwww.proceduresconsult.com/medical-procedures/nerve-blocks-of-the-face-EM-019-procedure.aspx

Tomaszewska, A; Kwiatkowska, B; Jankauskas, R. (2012) The localization of the supraorbital notch or foramen is crucial for headache and supraorbital neural avoiding and treatment. *Anat Rec* 295: 1494 – 1503

Turhan-Haktanır, N; Ayçiçek, A; Haktanır, A; Demir, Y. (2008) Variations of Supraorbital Foramina in Living Subjects Evaluated with Multidetector Computed Tomography. *Head & Neck* 30: 1211 – 1215

Voronov, P; Suresh, S. (2008) Head and neck blocks in children. *Curr Opin Anaesth* 21: 317 – 322

Wells, M. (2010) Local and regional anaesthesia in the emergency department made easy. Churchill Livingstone Elsevier

Young, WB; Marmura, M; Ashkenazi, A; Evans, RW. (2008) Greater occipital nerve and other anesthetic injections for primary headache disorders. Expert opinion. *Headache* 48: 1122 – 1125

Zaizen, T; Sato, I. (2014) A morphological study of the multi infraorbital canals of the maxilla in the Japanese macaque by cone-beam computed tomography. *Anat sci Int* 89(3): 171 - 182

Zide, BM; Swift, R. (1998) How to block and tackle the face. *Plast Reconst Surg* 101(3): 840 – 851

4 Superficial cervical plexus nerve block

4.1 Introduction

The ventral rami of the upper four cervical spinal nerves (C1 – C4) form the cervical plexus (Mousel, 1941; Belvis *et al.,* 2007; Standring, 2008; Tran *et al.,* 2010; Herring *et al.,* 2012). This plexus is responsible for innervating muscles of the neck, the diaphragm and skin on the head, neck and upper chest. It lies posterior to the sternocleidomastoid muscle, internal jugular vein and deep fascia of the neck, and anterior to the levator scapulae and middle scalene muscles (Standring, 2008).

The anterior rami of the second, third and fourth cervical nerves divide into ascending and descending branches that unite to form continuous loops (Mousel, 1941; Standring, 2008). The branches arising from the plexus are divided into a superficial group and a deep group (Mousel, 1941). The sensory superficial branches arise from the loops before piercing the investing layer of deep cervical fascia to eventually supply the skin of the head, neck and chest. The deeper branches originating from the loops are generally responsible for motor supply to muscles of the neck (Standring, 2008). Tobias (1999) states: "The superficial cervical plexus provides sensory innervation to the neck, whereas the deep cervical plexus carries motor innervation. Anaesthesia of the latter provides only muscle relaxation without additional sensory blockade."

There is consensus in the literature that the cutaneous branches are related to the sternocleidomastoid muscle, even though the descriptions differ:

- Gupta and co-workers (2013) report that during dissection the cutaneous branches are seen at the posterior border of the sternocleidomastoid muscle. They describe this point as a "nerve point".
- The cutaneous branches emerge at the posterior border of the sternocleidomastoid muscle, at the level of the superior border of the thyroid cartilage (Herring et al., 2012).

- Mousel (1941) states that these branches emerge posterior to the lateral border of the sternocleidomastoid muscle, after which they turn anteriorly to pass superficially over the sternocleidomastoid muscle, deep to the platysma muscle.
- The superficial cervical plexus wraps around the muscular belly of the clavicular head of the sternocleidomastoid muscle (Suresh and Voronov, 2006; Belvis et al., 2007).
- Ramachandran and colleagues (2011) report that cutaneous cervical nerves travel around the middle of the posterior border of the sternocleidomastoid muscle, then cross this muscle by passing deep to the external jugular vein towards the anterior border.
- “The superficial cervical plexus is derived off the C3 / C4 nerve root. It wraps around the belly of the sternocleidomastoid and terminates in four major branches” (Suresh and Voronov, 2012).

The sternocleidomastoid muscle is an important landmark in the cervical region, dividing the neck into the anterior and lateral cervical regions. This key muscular landmark is thick and narrow in the central part and broader and thinner at each end. It ascends obliquely from the clavicle and manubrium where the two heads originate, towards the lateral surface of the mastoid process of the temporal bone and the superior nuchal line of the occipital bone where it inserts. The sternal head, attaching to the manubrium of the sternum is rounded and tendinous, while the clavicular head, originating from the superior surface of the medial third of the clavicle, contains muscular and fibrous elements (Moore and Dalley, 2006; Standring, 2008).

The sternocleidomastoid muscle is a superficial muscle covered by the platysma muscle and skin. Between the superficial coverings and the muscle, the external jugular vein descends, and the great auricular and transverse cervical nerves also cross the muscle. Deep to the sternocleidomastoid muscle, the carotid sheath and subclavian artery can be located, along with infrahyoid muscles, cervical and brachial plexuses and other neurovascular structures (Standring, 2008).

According to Tubbs and co-workers (2007), the point where the cutaneous branches of the cervical plexus emerge, is often incorrectly referred to as Erb's point. This specific point is described as a "superficial point 2 – 3 cm superior to the clavicle, 'somewhat outside of the posterior border of the sternocleidomastoid'", at the level of C6. The middle of the posterior border of the sternocleidomastoid muscle is referred to as the nerve point of the neck (Moore and Dalley, 2006). It is at this point where the cutaneous branches of the cervical plexus emerge superficially (Moore and Dalley, 2006; Gupta *et al.,* 2013). The nerve point is located at the level of C3 or the hyoid bone (Tubbs *et al.,* 2007), and is also referred to as punctum nervosum (Tubbs *et al.,* 2007; Alilet *et al.,* 2016). Tubbs and colleagues (2005) found the point where the cutaneous branches of the cervical plexus emerge superficially to be located approximately 6 cm inferior to the tip of the mastoid process. Nevertheless, Erb's point (C6 vertebral level) is located inferior to the nerve point of the neck (Tubbs *et al.,* 2007).

The four terminal cutaneous branches of the superficial cervical plexus are the great auricular, lesser occipital, transverse cutaneous cervical and supraclavicular nerves (Belvis *et al.,* 2007; Standring, 2008; Herring *et al.,* 2012). Each of these nerves has a specific distribution that can be anaesthetised to assist with pain management (Suresh and Voronov, 2012).

The great auricular nerve (C2 – C3) is the largest branch of the superficial cervical plexus (Belvis *et al.,* 2007; Standring, 2008; Herring *et al.,* 2012; Pillay *et al.,* 2012) and innervates the frequently injured auricle of the ear (Herring *et al.,* 2012). This ascending branch perforates the deep cervical fascia and travels posterior to the clavicular head of the sternocleidomastoid muscle, deep to the platysma muscle en route to the parotid gland (Suresh and Voronov, 2006). This nerve runs on the sternocleidomastoid muscle parallel to the external jugular vein (Standring, 2008). The great auricular nerve divides into an anterior branch that innervates the skin of the face over the parotid gland, and a posterior branch that supplies the skin behind the auricle and over the mastoid process (Suresh and Voronov, 2006). Moore and Dalley (2006) describe the distribution of the great auricular nerve as a cutaneous branch that supplies the skin and sheath covering the parotid gland, both surfaces of the auricle, as well as the skin located between the mastoid process and the angle of the mandible.

The lesser occipital nerve (C2) arises from the nerve loop between the anterior rami of C2 and C3 and supplies the scalp posterosuperior to the auricle and the skin of the neck (Moore and Dalley, 2006). According to Herring and co-workers (2012), the lesser occipital nerve (C2 – C3) supplies the skin of the posterior neck and scalp, posterior to the auricle. Standring (2008) reports that the lesser occipital nerve is mainly derived from the second cervical nerve, even though fibres from the third cervical spinal nerve may contribute to this nerve. It is related to the spinal accessory nerve and ascends along the posterior border of the sternocleidomastoid muscle. This nerve perforates the deep fascia to supply the skin behind the auricle and connects with the great auricular and greater occipital nerves, as well as the auricular branch of the facial nerve (Standring, 2008).

The transverse cervical nerve (C2 – C3) travels towards the midline and supplies the skin between the sternum and the mandible, on the anterolateral side of the neck (Herring *et al.,* 2012). The transverse cervical nerve arises from the nerve loop between the anterior rami of the second and third cervical nerves and curves around the middle of the posterior border of the sternocleidomastoid muscle towards the anterior border of the muscle. It crosses the sternocleidomastoid muscle horizontally, deep to the external jugular vein (Moore and Dalley, 2006; Standring, 2008). Deep to the platysma muscle, the transverse cervical nerve divides into ascending and descending branches (Standring, 2008) or superior and inferior branches (Moore and Dalley, 2006). These branches innervate the anterior cervical region between the mandible and the sternum (Standring, 2008). According to the results obtained in a study conducted by Ella and co-workers (2015), the transverse cervical nerve is responsible for accessory innervation of the skin over the mandible.

The supraclavicular nerve (C3 – C4) descends through the posterior triangle of the neck and divides into three branches deep to the platysma muscle (Ramachandran *et al.,* 2011; Herring *et al.,* 2012). Standring (2008), as well as Moore and Dalley (2006), mention that the supraclavicular nerves start as a common trunk which divides deep to the platysma muscle into medial, intermediate and lateral branches. The areas innervated by these nerves include the skin over the clavicle, sternoclavicular joint and acromioclavicular joint, which are commonly injured areas (Herring *et al.,* 2012). These lower branches of the plexus also innervate the pectoral region (Mousel, 1941). Ramachandran and colleagues (2011) report that the supraclavicular nerves perforate the deep cervical fascia and the platysma muscle near the clavicle to innervate the skin over the inferior portion of the sternocleidomastoid muscle and clavicle, as well as the pectoralis major and deltoid muscles and upper and posterior shoulder.

Gupta and co-workers (2013) make the following statement: “The variable sites and the distributions of the cervical cutaneous nerves lead to surgical complications during the performance of the anaesthetic technique.” They continue to say that the previously mentioned reason is why anaesthesia of each separate branch is often difficult to achieve and that more studies on the branching patterns and distributions of the cervical cutaneous nerves are required.

4.1.1 Indications

From the literature, it is evident that cervical plexus nerve blocks are most commonly performed in adults during carotid endarterectomy (Stoneham *et al.,* 1998; Merle *et al.,* 1999; Stoneham and Knighton, 1999: Pandit *et al.,* 2000; Pandit *et al.,* 2003; Gomes *et al.,* 2010; Ramachandran *et al.,* 2011; Vaniyapong *et al.,* 2013; Pasin *et al.,* 2015; Alilet *et al.,* 2016; Kavakli *et al.,* 2016), and surgery related to the thyroid gland (Mousel, 1941; Saxe *et al.,* 1988; Yerzingatsian, 1989; Dieudonne *et al.,* 2001; Aunac *et al.,* 2002; Andrieu *et al.,* 2007; Herlich, 2012; Egan *et al.,* 2013; Karthikeyan *et al.,* 2013), and parathyroid glands (Saxe *et al.,* 1988; Herlich, 2012; Egan *et al.,* 2013; Su *et al.,* 2015).

Vaniyapong and colleagues (2013) report in a Cochrane review on anaesthesia use for carotid endarterectomy, that approximately 20% of patients experiencing transient ischaemic attacks or non-disabling ischaemic strokes, suffer from a carotid stenosis, as well as an unstable atheromatous plaque at or near the bifurcation of the common carotid artery. Carotid endarterectomy is performed preventatively in order to reduce the incidence of a possible embolic and thrombotic stroke (Stoneham and Knighton, 1999). During this procedure atheroma is removed from the internal carotid artery (Gomes *et al.,* 2010) as well as the stenosis in the ipsilateral carotid artery (Vaniyapong *et al.,* 2013).

Carotid endarterectomy is often performed using local anaesthesia rather than general anaesthesia in order to prevent risks associated with general anaesthesia. Local anaesthesia also allows for the assessment of neurological functions following carotid clamping (Gomes *et al.,* 2010; Alilet *et al.,* 2016). Stoneham and Knighton (1999) state: “Regional anaesthesia is suitable for any of the surgical approaches to the carotid artery, including transverse and vertical incisions, although local anaesthetic supplementation will be required if a transverse incision crosses the midline.”

A regional nerve block for carotid endarterectomy requires anaesthesia of the second to the fourth cervical spinal nerves (Pandit *et al.,* 2010). This can be done either through a superficial cervical plexus block, intermediate cervical plexus block, deep cervical plexus block or a combined superficial and deep cervical plexus block (Kavakli *et al.,* 2016). However, the deep cervical plexus block has been associated with complications such as intravascular injection of the vertebral artery, intrathecal injection, as well as respiratory failure or distress (Pandit *et al.,* 2007). Pandit and co-workers (2000) concluded in their study that a superficial cervical plexus nerve block is sufficient for carotid endarterectomy, and supplementing this procedure with a deep block provides no additional benefit.

Neck surgeries related to thyroidectomies are not considered very painful, thus resulting in pain relief often being neglected (Bagul *et al.,* 2005). Yet, Dieudonne and co-workers (2001) report that several patients who underwent thyroid surgery with general anaesthesia may require postoperative pain relief during the first day. Postoperative pain relief can be managed through the use of non-steroidal anti-inflammatory drugs or opioids. However, these are often avoided due to the possibility of complications. Local anaesthesia through wound infiltration can decrease post-thyroidectomy pain (Dieudonne *et al.,* 2001). Bilateral superficial and deep cervical plexus blocks have also been successfully used for a thyroidectomy in a pregnant patient in order to avoid the risks associated with general anaesthesia (Goktas *et al.,* 2013).

The surgical field related to thyroid surgery is innervated by the superficial cervical plexus (Bagul *et al.,* 2005). Aunac and co-authors (2002) conclude in their study that a bilateral superficial and cervical plexus block reduced intraoperative and postoperative analgesic requirements for patients undergoing thyroidectomy. This is confirmed in a study conducted by Andrieu and co-workers (2007), that iterates that a bilateral superficial cervical plexus block reduces pain experienced during and after thyroid surgery. Karthikeyan *et al.* (2013) conducted a randomized control trial. Their findings coincide with the aforementioned studies, that a bilateral superficial cervical plexus nerve block with additional 0.25% bupivacaine can be used preventatively to reduce intraoperative and postoperative pain.

Following a clinical trial, Egan and colleagues (2013) resolve that pain experienced after thyroid~, as well as parathyroid surgery, can effectively be managed with intraoperative superficial cervical plexus nerve block and minimal analgesics. Both thyroidectomy and parathyroidectomy can be performed using only local anaesthetics (Herlich, 2012). Saxe and co-workers (1988) reported that they completed 17 thyroid surgeries and two parathyroid surgeries using only regional anaesthesia.

Su *et al.* (2015) investigated the analgesic efficacy of bilateral superficial and deep cervical plexus nerve blocks in patients suffering from hyperparathyroidism due to chronic renal failure. They determined that a superficial cervical plexus block, or a combined superficial and deep cervical plexus block in conjunction with general anaesthesia, effectively reduces postoperative pain, resulting in a decreased incidence of complications such as nausea and vomiting. They also state that no significant difference in analgesic efficacy was observed between the superficial and combined plexus blocks, but that the bilateral superficial cervical plexus block is a safer alternative than the combined superficial and deep cervical plexus block.

Other indications for superficial cervical plexus blocks in adults include parotidectomy (Chow *et al.,* 2013), laryngectomy and operations on the skin of the neck and over the mastoid process and ear (Mousel, 1941), as well as postoperative relief of laparoscopic shoulder pain (Kanawati *et al.,* 2015) and anterior cervical discectomy and fusion (Mariappan *et al.,* 2015). Matsunami and colleagues (2015) reported a case of a 69-year old woman with athetoid cerebral palsy who underwent posterior cervical spinal fusion and had complete anaesthesia of the area after successfully receiving a frontal nerve, greater occipital nerve and superficial cervical plexus nerve block.

Herring and co-workers (2012) report on the following incidences where an ultrasound-guided superficial cervical plexus block was used in an emergency setting:

- Treatment of severe pain related to an acute clavicular fracture;
- Ear lobe lacerations;
- Submandibular abscesses;
- Injuries to the neck.

Similar to adults, the superficial cervical plexus is often blocked in paediatric patients undergoing surgery to the thyroid gland (Dieudonne *et al.,* 2001; Aunac *et al.,* 2002; Voronov and Suresh, 2008; Roberts and Cowen, 2016).

Suresh and Voronov (2012) report that in paediatric patients, the individual branches are often blocked for specific cases such as the great auricular and lesser occipital nerve blocks for patients undergoing tympanomastoid surgery, as well as cochlear implants. The transverse cervical nerve block can be performed for patients undergoing thyroplasty and thyroid surgery, while the supraclavicular nerve block provides analgesia of the skin of the shoulder and neck.

The superficial cervical plexus block can also be used in paediatric patients for brachial cleft cyst excision (Voronov and Suresh, 2008), mastoidectomy and otoplasty (Suresh, 2003), tympanomastoid surgery (Suresh *et al.,* 2002; Suresh *et al.,* 2004), bilateral simultaneous cochlear implantation (Merdad *et al.,* 2012), as well as superficial neck surgery relating to branchial cyst / fistula, tracheostomy and tunnelled central venous cannulation (Roberts and Cowen, 2016).

Belvis *et al.* (2007) list vocal cord surgery, as well as excision of moles and cysts, as indications for superficial cervical plexus blocks. In conjunction with a greater occipital and supraorbital nerve block, the superficial cervical plexus block was performed in a very low-birth-weight neonate that underwent an Ommaya reservoir placement for hydrocephalus (Suresh and Bellig, 2004).

Tobias (1999) made the following statement: “However, many of the regional techniques also can be used instead of general anaesthesia in circumstances where anatomical or physiologic alterations may make the conduct of general anaesthesia more difficult or dangerous.” He reported two cases in which the superficial cervical plexus block was successfully used on adolescents with anatomically altered airways. In one case, the patient presented with an excision of a superficial and deep anterior cervical lymph node, while the second patient underwent excision of a left thyroid nodule.

Tobias (1999) concludes the case reports with a statement that iterates that careful attention should be paid to the amount of local anaesthetic used and the exact location of the nerve block. Cervical plexus nerve blocks can be successfully used in the paediatric population. Therefore, more research needs to be conducted in order to successfully identify the landmarks used in blocking the superficial cervical plexus in the paediatric population.

4.1.2 Contra-indications

Regional anaesthesia contra-indications that are not specific to any regions, include:

- Patients with known allergies to local anaesthetics used (Saxe *et al.,* 1988; Stoneham *et al.,* 1998; Pandit *et al.,* 2000; Suresh *et al.,* 2002; Karthikeyan *et al.,* 2013; Ramachandran *et al.,* 2013; Alilet *et al.,* 2016).
- Infection at the site of the proposed nerve block (Stoneham *et al.,* 1998; Suresh and Wheeler, 2002; Pasin *et al.,* 2015; Roberts and Cowen, 2016).

- Patient anxiety about the specific regional anaesthetic technique (Saxe *et al.,* 1988).
- Patient's refusal of regional anaesthesia (Tran *et al.,* 2010; Pasin *et al.,* 2015) or lack of consent (Roberts and Cowen, 2016).

Saxe and colleagues (1988) reported that contra-indications for thyroid and parathyroid surgeries using regional anaesthesia include palsy of the recurrent laryngeal or phrenic nerves, deafness, or high spinal cord injury. Karthikeyan *et al.* (2013) state that the contra-indications for the superficial cervical plexus block in thyroidectomies include local infection or sepsis, as well as bleeding conditions.

Pandit and collaborators (2000), as well as Ramachandran *et al.* (2013) and Alilet *et al.* (2016), investigated regional nerve blocks for carotid endarterectomies and excluded patients suffering from known bleeding conditions, as well as contra-lateral diaphragmatic motion abnormalities or local sepsis, from their studies. For the latter study, patients with severe chronic pulmonary disease or previous cervical surgery or radiotherapy were also excluded from the research study.

Suresh and Wheeler (2002) report that paediatric patients often have the same contra-indications as adults towards peripheral nerve blocks, such as coagulopathy, infection at the block site, general sepsis, predisposition to compartment syndrome, or the opposition of the parent or child to the regional anaesthetic technique.

In a study conducted by Suresh and co-workers (2002), where the effect of a regional block in relation to opioids for tympanomastoid surgery was evaluated, they excluded paediatric patients with a history of respiratory, cardiac, renal, hepatic or neurological conditions.

4.1.3 Step-by-step procedure

The superficial cervical plexus nerve block is often performed either through the use of ultrasound, or a technique that makes use of landmarks.

In three studies where the superficial cervical plexus block was performed using ultrasound-guided approaches, the posterior border of the sternocleidomastoid muscle was visualised on the screen (Tran *et al.,* 2010; Herring *et al.,* 2012; Roberts and Cowen, 2016). Tran and colleagues (2010) used the midpoint of the posterior border of the sternocleidomastoid muscle, while Herring *et al.* (2012) used the level of the cricoid cartilage to identify the location of the cutaneous branches of the cervical plexus. In the study conducted by Alilet and colleagues (2016), the ultrasound probe was placed perpendicular to the skin in the horizontal plane at C3 - C4 level and the needle was inserted between the inferior border of the levator scapulae muscle and the posterior border of the sternocleidomastoid muscle.

The landmark-based technique that is predominantly used, also makes use of the posterior border of the sternocleidomastoid muscle (Alilet *et al.,* 2016). However, the descriptions with regard to the exact location and the injections differ:

- The needle is inserted superficially below the skin, at the level of C3 – C4 in order to locate the nerve point. The anaesthetic solution is then injected in a fan-like manner, in the subcutaneous plane (Alilet *et al.,* 2016).
- The injection site is located at the midpoint of the posterior border of the sternocleidomastoid muscle, and 5ml is injected in a cephalic as well as a caudal, direction respectively (Eti *et al.,* 2006; Tran *et al.,* 2010; Karthikeyan *et al.,* 2013). Eti and collaborators (2006), as well as Karthikeyan *et al.* (2013), also injected 5ml horizontally, superficial to the muscle. The same technique is used by Dieudonne *et al.* (2001), however, with different volumes of anaesthetic solution.
- The anaesthetic solution is injected along the posterior border of the sternocleidomastoid muscle, between the deep fascia of the neck and the sternocleidomastoid muscle (Mousel, 1941).
- Andrieu and colleagues (2007, used a three-point injection technique in their research study. The needle was inserted 2cm superior to the clavicle and anaesthetic fluid was injected in a cephalic direction, after an aspiration test. The needle was then redirected medially in order to

successfully block the transverse cervical nerves, after which the remaining mixture was injected subcutaneously at the point of entry.

- Ramachandran *et al.* (2011) and Pasin *et al.* (2015) performed superficial cervical plexus blocks by injecting the anaesthetic solution subcutaneously along the entire posterior border of the sternocleidomastoid muscle.
- At the midpoint of the sternocleidomastoid muscle, the anaesthetic agent is injected along the posterior border of the sternocleidomastoid in a cephalic and caudal direction, both superficial and deep to the fascia of the sternocleidomastoid muscle. “A ‘fan’ injection was also performed subcutaneously from the posterior border of sternocleidomastoid toward the midline of the neck” (Pandit *et al.,* 2000).
- Merle and co-workers (1999) report that they performed the cervical superficial plexus block by infiltrating the anaesthetic solution at the midpoint of the sternocleidomastoid muscle for approximately 60 seconds.
- A superficial cervical plexus block can easily be performed by injecting the anaesthetic solution along the middle third of the posterior border of the sternocleidomastoid muscle (Herlich, 2012).
- “The superficial block was performed by using the same needle inserted at the midpoint of the lateral border of the sternocleidomastoid muscle” (Su *et al.,* 2015).
- Mariappan and colleagues (2015) drew a line between the mastoid process and the clavicular head of the sternocleidomastoid muscle. A needle was then inserted at the midpoint of this line, between the anterior and posterior borders of the sternocleidomastoid muscle. The anaesthetic solution was injected through the fan-shaped technique, 2 - 3cm superiorly and inferiorly from the injection site.
- At the midpoint of the posterior border of the sternocleidomastoid, the anaesthetic solution is injected subcutaneously, cranially and caudally, along the posterior border of the sternocleidomastoid from the injection point (Stoneham *et al.,* 1998; Stoneham and Knighton, 1999).

- In order to block the main branches of the superficial cervical plexus, 6ml solution is injected at the midpoint of the lateral border of the sternocleidomastoid muscle in four directions (Aunac *et al.,* 2002).
- “Local anaesthetic is deposited midway along the length of the sternocleidomastoid muscle overlying an area where all the cutaneous branches are distributed in the neck. The injection is usually given superficial to the investing layer of deep fascia” (Yerzingatsian, 1989).
- Chow and colleagues (2013) state that they use the midpoint between the mastoid process and the sternal head of the sternocleidomastoid muscle to block the superficial cervical plexus.

The majority of the abovementioned techniques use the midpoint of the sternocleidomastoid muscle as the insertion point to block the superficial cervical plexus. However, a standardised technique needs to be developed.

In the paediatric population, the techniques used are to a certain degree similar to those used in adults:

- Roberts and Cowen (2016) suggest using ultrasound guidance and placing the probe lateral to the posterior border of the sternocleidomastoid muscle. The superficial cervical plexus should be approached from a lateral direction immediately deep to the sternocleidomastoid muscle.
- “The sternocleidomastoid muscle is identified, and the C6 hyoid prominence is identified. The nerve wraps around the belly of the sternocleidomastoid at the level of the C6 prominence.” The anaesthetic solution is injected subcutaneously after which the area is massaged to facilitate the spread of the solution (Suresh and Voronov, 2012).
- When performing a superficial cervical plexus nerve block in adolescent patients, Tobias (1999) deposits the anaesthetic solution at the midpoint of the posterior border of the sternocleidomastoid muscle and infiltrates deep to the muscle belly along the entire posterior border of the sternocleidomastoid muscle.

- The superficial cervical plexus can be located at the intersection of a line drawn from the superior border from the cricoid cartilage to the posterior border of the sternocleidomastoid muscle (Suresh and Wheeler, 2002; Suresh, 2003; Suresh *et al.,* 2004; Suresh and Voronov, 2006; Voronov and Suresh, 2008). Voronov and Suresh (2008) state that the 45-degree bent needle is directed superiorly at the intersection point, to inject along the posterior border of the sternocleidomastoid muscle.
- At the level of C6, Belvis and co-workers (2007) passed a needle with a 60-degree bend cranially along the posterior border of the sternocleidomastoid muscle.
- Merdad *et al.* (2012) block the superficial cervical plexus at the midpoint of the posterior border of the sternocleidomastoid muscle. "This roughly corresponds to the level of C3/C4." A needle was then inserted along the posterior border of the clavicular head of the sternocleidomastoid muscle.

In the studies by Suresh and Wheeler (2002), Suresh (2003), Suresh *et al.* *(*2004), Suresh and Voronov (2006), Voronov and Suresh (2008) and Suresh and Voronov (2012), the great auricular nerve is discussed, yet, the technique described is effective in blocking all the cutaneous branches of the superficial cervical plexus.

Alilet *et al.* (2016) conducted a trial to compare the ultrasound-guided intermediate cervical block and the landmark-based superficial cervical plexus block. The main conclusion from the trial is that both the landmark-based and ultrasound-guided nerve blocks are similarly effective. Likewise, Ramachandran and colleagues (2011) reported that blindly performing the intermediate and subcutaneous cervical plexus nerve blocks is equally effective.

Roberts and Cowen (2016) make the following valid statement: "Ultrasound enables more accurate placement of local anaesthesia by providing non-invasive information regarding the anatomy and needle trajectory, reducing potential damage to adjacent structures." However, in certain parts of the world the lack of availability of imaging technology, such as ultrasound, needs to be taken into account. The development of landmark-based techniques is thus a vital necessity, especially in the paediatric population.

Suresh and Voronov (2012) state that this technique can be easily performed using the landmark technique. Yet, different landmark-based techniques are described, using several different landmarks or intersection points.

4.1.4 Anatomical pitfalls

From the literature, the biggest anatomical pitfall encountered during the performance of the superficial cervical plexus nerve block, especially in paediatric patients, is the incorrect placement of the needle. “The main problem is the difficulty in ascertaining the proper needle location below the posterior part of the sternocleidomastoid muscle” (Alilet *et al.,* 2016).

In the event of a patient not receiving adequate relief of postoperative pain, an increased level of stress hormones and perioperative complications might be experienced (Su *et al.,* 2015). Bagul and co-workers (2005) make the following statement: “Pain can be arrested at the periphery by blocking peripheral nerves or at the central nervous system by modulating pain pathways.” In order to successfully block these nerves at the periphery and achieve adequate postoperative pain relief, knowledge on the anatomical structures is required.

Suresh and Wheeler (2002) state that the location of the external jugular veins and carotid arteries should be noted in order to prevent intravascular injections. In a study conducted by Pillay and collaborators (2012), a duplicate external jugular vein was observed in 5% of specimens dissected. Suresh and co-workers (2002) emphasize that care should be taken when nerve blocks are performed in the vicinity of vital structures. Thus, accurate and detailed descriptions of the superficial cervical plexus in relation to structures such as the external jugular vein, as well as possible variations that may be encountered, are required.

Tobias (1999) also states that a concern with paediatric anaesthesia is the total amount of local anaesthetic used during the performance of a regional nerve block. The author is of the opinion that, due to a lack of anatomical knowledge, the superficial cervical plexus nerve block is often performed using multiple injections. Merle and co-workers (1999) concluded in their study that with the single injection technique, the concern of systemic absorption of the local anaesthetic is less than with the multiple injection technique. Thus, if a technique is adequately described and can easily be performed by the practising anaesthesiologist and / or surgeon, it will ensure that the block can be successfully performed without the need for excessive anaesthetic solution.

The superficial cervical plexus nerve block is simpler to perform than the deep cervical plexus nerve block (Stone and Knighton, 1999). Pandit and colleagues (2000) state that, not only is the superficial cervical plexus nerve block as effective as the deep or combined nerve block, but it is also easier to perform and teach, and associated with fewer complications.

“Head and neck blocks can be performed safely in children using well described and easily identified anatomical landmarks” (Voronov and Suresh, 2008). Therefore, the anatomical landmarks and techniques that will be used to safely perform the superficial nerve block need to be adequately described, especially in the paediatric population, to ensure minimal complications and decreased postoperative morbidity.

4.1.5 Complications and side-effects

Roberts and Cowen (2016) make the following statement regarding paediatric patients, which is also applicable to adult patients: “Peripheral techniques are considered safer than neuroaxial techniques as complications such as bleeding and infection are less severe.” Stoneham and Knighton (1999) also report that the cervical plexus block has fewer cardiovascular side effects and only affects the unilateral nerve roots. It is therefore a safer alternative.

Merle and collaborators (1999) state: “The most common complication is systemic local anaesthetic toxicity, caused by either intravascular injection or vascular absorption in this highly vascularized region.” This statement is supported by Kavakli *et al.* (2016) who emphasize that, due to the close proximity of the vertebral artery to the second, third and fourth cervical spinal nerves, intravascular injection is a possibility. In the study by Pasin and colleagues (2015), one patient had seizures after the cervical plexus block was administered for carotid endarterectomy. This was associated with accidental vertebral injection or local anaesthetic systemic toxicity. Even if small amounts of anaesthetic solution are injected intravascularly, especially into the vertebral artery, it can lead to damaging complications. This can be avoided should negative aspiration be performed (Tobias, 1999).

Other complications or side-effects experienced with superficial cervical plexus nerve block include:

- Haematomas (Egan *et al.,* 2013; Alilet *et al.,* 2006);
- Bradyasystole arrest, which is attributed to a vagal reflex (Pasin *et al.,* 2015);
- Transient vocal cord paralysis (Lee *et al.,* 1988);
- Difficulty in swallowing (Tran *et al.,* 2010);
- Coughing and facial palsy (Kavakli *et al.,* 2016);
- Temporary hypoglossal nerve palsy (Lee *et al.,* 1988; Alilet *et al.,* 2016);
- Hoarseness (Tran *et al.,* 2010; Alilet *et al.,* 2016; Kavakli *et al.,* 2016);
- Total spinal anaesthesia due to intrathecal injection (Tobias, 1999).

Herring *et al.* (2012) report that the biggest complications of the superficial cervical plexus occurs due to the deep injection of the local anaesthetic solution, that can result in blockade of the deeper neural structures such as the phrenic nerve, deep cervical plexus, brachial plexus, as well as the recurrent laryngeal nerve.

According to Andrieu and collaborators (2007), the deep cervical plexus block is associated with more serious complications such as phrenic nerve palsy. “However, bilateral deep cervical plexus blocks can produce a highly dangerous bilateral diaphragmatic dysfunction. In view of the potential risks, we consider that this potentially unsafe technique should not be used for postoperative pain relief" (Dieudonne *et al.,* 2001). In comparison, they report that the bilateral superficial cervical plexus block was not associated with an increased occurrence of recurrent nerve paralysis, due to the diffusion of the anaesthetic solution.

In a Cochrane review conducted by Vaniyapong *et al.* (2013) on local and general anaesthesia for carotid endarterectomies in adults, the complications encountered included stroke, death, myocardial infarction, local haemorrhage, cranial nerve injuries and pulmonary complications. However, no statistical significance was observed between the two types of anaesthesia for each of these complications.

The following complications or side-effects related to paediatric patients have been encountered from the literature:

- Should the deep cervical plexus be blocked, Horner's syndrome could occur (Suresh and Wheeler, 2002; Suresh, 2003; Suresh and Voronov, 2006; Belvis *et al.,* 2007);
- Blocking of the phrenic nerve unilaterally, affecting the hemi-diaphragm (Stoneham and Knighton, 1999; Belvis *et al.,* 2002; Suresh and Wheeler, 2002; Suresh, 2003; Voronov and Suresh, 2008);
- Deep injection affecting the trapezius muscle due to the blocking of the spinal accessory nerve (Suresh and Wheeler, 2002);
- Haematoma (Belvis *et al.,* 2002; Suresh and Voronov, 2006; Voronov and Suresh, 2008; Suresh and Voronov, 2012);
- Small erythematous area at the site of the injection (Suresh, 2003)
- Postoperative fever (Merdad *et al.,* 2012);
- Pneumothorax and subarachnoid / epidural injection (Roberts and Cowen, 2016);
- Intravascular injection (Belvis *et al.,* 2002; Voronov and Suresh, 2008; Suresh and Voronov, 2012).

Pasin and co-workers (2015) make the following statement: “According to our experience, cervical plexus block, especially the superficial one, is an easy technique, with a rapid learning curve and with a low risk of complications.” Andrieu *et al. (*2007) concur with this statement, as long as the injection of the superficial cervical plexus block is performed subcutaneously.

Patient~ and family satisfaction, as well as early discharge, are aspects that are essential for satisfactory paediatric surgery. These are often achieved through good pain management, which results in a reduction of morbidity, and aids in the patient’s recovery (Roberts and Cowen, 2016). This, together with the statement by Belvis and co-workers (2007), that “recent publications elucidating new techniques for nerve localization coupled with a thorough understanding of the anatomy may encourage more practitioners to use these blocks in children”, are resulting in an increased use of nerve blocks in paediatric patients. Therefore, a detailed descriptive study with regard to the superficial cervical plexus nerve block in paediatric patients is required to assist practising anaesthesiologists and / or surgeons in understanding and applying the anatomical knowledge to successfully perform this regional nerve block.

4.2 Aims

The following aims will be addressed in this research chapter:

4.2.1 To provide a detailed description of the 'nerve point' in the neck and the relationship between the superficial cervical nerves and related landmarks such as the cricoid and thyroid cartilages, as well as the external jugular vein.

4.2.2 To establish the best method of blocking the superficial cervical plexus in the neck, in a paediatric population.

4.3 Materials and Methods

4.3.1 Cadaveric dissections

a. To provide a detailed description of the ‘nerve point’ in the neck and the relationship between the superficial cervical nerves and related landmarks such as the cricoid and thyroid cartilages, as well as the external jugular vein.

The nerve point of the neck was evaluated through a bilateral neck dissection in 24 paediatric cadavers, as seen in Figure 4.1. During the dissection, the entire sternocleidomastoid muscle, the superficial branches of the cervical plexus, as well as the external jugular vein were exposed and identified. None of these cadavers were previously dissected in the lateral neck region, or had any visible cervical abnormities.

The cadavers were placed in a supine position, with a small wooden block placed underneath the cervical region, in order to hyperextend the atlanto-axial joint, resulting in greater exposure of the anterolateral neck region. The skin was reflected laterally and the platysma muscle carefully removed to display the sternocleidomastoid muscle and the superficial cutaneous branches of the cervical plexus. The nerve point of the neck, where the cutaneous branches emerge posterior to the posterior border of the sternocleidomastoid muscle, as well as the external jugular vein, were exposed along the sternocleidomastoid muscle.

To successfully evaluate the relationship between the cutaneous branches of the cervical plexus and surrounding structures, the following landmarks were used:

- A – Nerve point of the neck (where the superficial cutaneous branches of the cervical plexus emerge around the posterior border of the sternocleidomastoid muscle);
- B – Lateral-most clavicular attachment of the sternocleidomastoid muscle;
- C – Mastoid process;
- D – Midline of the neck;

- E – External jugular vein;
- F – Transverse cervical nerve.

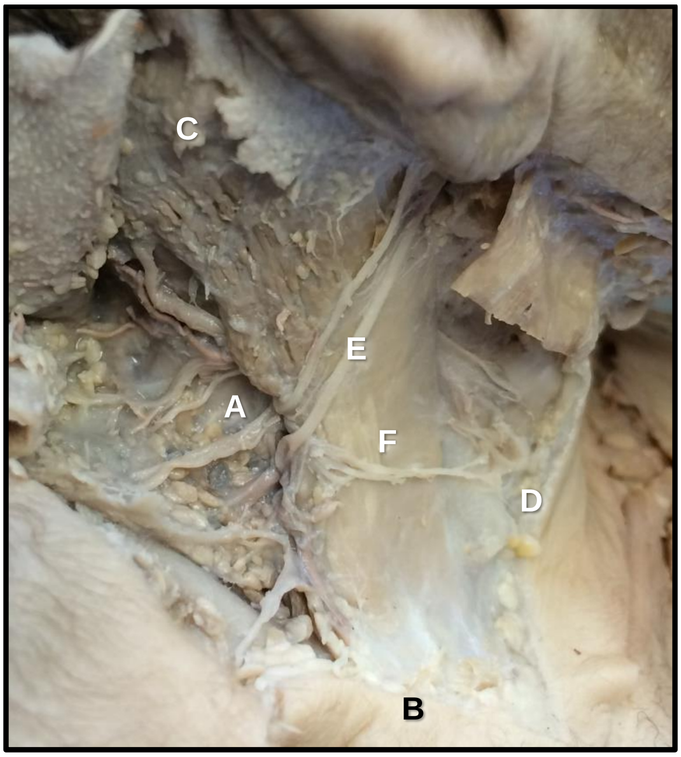


Figure 4.1: Dissection of the right side of the neck of a neonatal cadaver, revealing the superficial branches of the cervical plexus

The exact location of the nerve point was established through the following measurements and descriptions:

- The exact location of the nerve point (A), between the clavicular (B) and mastoid (C) attachments of the sternocleidomastoid muscle;
- The distance between the nerve point of the neck (A) and the midline of the neck (D);
- The level of the nerve point of the neck (A) with regard to midline structures (D) such as the hyoid bone, thyroid cartilage and cricoid cartilage;
- The distance between the nerve point of the neck (A) and the external jugular vein (F);
- The relationship between the transverse cervical nerve (F) and the external jugular vein (E).

The relationship between the abovementioned structures was observed and discussed. Quantitative measurements between these nerves and the bony and soft tissue landmarks will assist paediatric anaesthesiologists to successfully block the superficial branches of the cervical plexus with minimal complications.

b. To establish the best method of blocking the superficial cervical plexus in the neck, in a paediatric population.

The results obtained in (a), as well as all the techniques obtained from the literature, were compared and analysed to determine a standardised method of blocking the superficial cervical plexus in paediatric patients.

The distance from the nerve point of the neck, where the superficial branches of the cervical plexus emerge around the posterior border of the sternocleidomastoid muscle, to fixed bony and soft landmarks, will assist anaesthesiologists and surgeons perform this technique on paediatric patients. To further facilitate the calculation, the breadth of the fingers on the right hand was measured as follows:

- Breadth of the medial four fingers at the proximal interphalangeal joint;
- Breadth of the medial three fingers at the proximal interphalangeal joint;
- Breadth of the medial two fingers at the proximal interphalangeal joint;
- Breadth of the 5th digit / digitus manus minimus (little finger) at the proximal interphalangeal joint;
- Breadth of the thumb at the interphalangeal joint.

To ensure that the superficial cervical plexus can be successfully blocked in the paediatric population, easily understandable descriptions and techniques were developed. This was completed through calculations of the correlations between the distances obtained in (a), and the breadth of the fingers on the right hand of each cadaver. This ensured that clear and uncomplicated descriptions and distances for effectively blocking the superficial cervical plexus could be developed.

4.3.2 Statistical analysis

After completing the dissection of the 24 paediatric cadavers which comprised of 22 neonatal cadavers (Group 1) and two infant cadavers (Group 2), measurements were obtained from the superficial cervical plexus to bony and soft tissue landmarks. This was performed using a Vernier digital calliper (accuracy of 0.01mm). All the acquired measurements were captured in a separate MS Excel data sheet in order to complete the statistical analysis.

To develop the most accurate and uncomplicated method of blocking the superficial cervical plexus, the obtained data was analysed through statistical comparisons using SAS® analytical software. This included:

- The mean or average value of each measurement;
- The standard deviation in order to establish the range of the sample;
- 95% confidence interval to establish the true population value for the statistic value, including upper and lower ranges.

Due to the torsion of the cervical region of the paediatric cadavers, not all cadavers were dissected bilaterally. A total of 21 dissections were performed on the right anterolateral aspect of the neck, while 19 dissections were completed on the left cervical region. Even though only 16 cadavers were dissected bilaterally, a paired T-test was performed in order to ascertain whether there is a significant difference between the right and the left cervical regions. A p-value of < 0.05 was regarded as statistically significant.

The second aim of this research chapter was to formulate a standardised method of blocking the superficial cervical plexus in a paediatric population. In order to successfully complete the nerve block, the exact location of the nerve point of the neck needed to be established.

As established earlier in this chapter, the most described method of blocking the superficial cervical plexus is by using the midpoint of the posterior border of the sternocleidomastoid muscle. In order to determine whether the nerve point was located in the middle of the posterior border of the sternocleidomastoid muscle, the relationship between the length of the sternocleidomastoid muscle and the location of the nerve point was determined. The exact relationship to the structures in the midline of the neck was also observed.

In order to develop a technique that can be easily performed, the information obtained in the first aim was used and compared to the breadth of the fingers on the right hand of each individual cadaveric specimen. Through this comparison, a Pearson population correlation coefficient was determined to establish a correlation between the two sets of variables. A correlation coefficient greater than 0.80 was considered as a positive relationship between the two sets of variables.

4.4 Results

As calculated in Chapter 1, no statistically significant difference was observed between the left and right side measurements obtained from the cadavers. Therefore, all measurements of the right and left sides were combined as the total sample. However, due to certain criteria, some measurements were not obtainable on all the specimens. This will be addressed as the results are reported.

The first aim of this research chapter is to provide a detailed description of the ‘nerve point’ in the neck and the relationship between the superficial cervical nerves and related landmarks such as the cricoid and thyroid cartilages, as well as the external jugular vein. The results of this aim will be subdivided according to specific landmarks.

4.4.1 Superficial cervical plexus to bony landmarks

4.4.1.1 Simulation on neonatal cadavers

The measurements for the 22 neonatal cadavers (Group 1) that fall between the age range 0 – 28 days after birth are displayed in Table 4.1. Of the 22 neonatal cadavers, 14 were dissected bilaterally, five on the right side only and three on the left side only. A total of 19 right side dissections and 17 left side dissections were completed.

Table 4.1: Relationship between the superficial cervical plexus nerves, emerging at the nerve point of the neck, and bony landmarks for Group 1

	Length SCM	Distance MP - NP	Distance NP - Clavicle
n	30	30	30
Mean	37.81	17.00	20.80
SD	7.58	5.91	4.24
CI95%	2.71	2.12	1.52
Lower	35.09	14.89	19.28
Upper	40.52	19.12	22.32

Key:

SCM: Sternocleidomastoid muscle
MP: Mastoid process
NP: Nerve point of the neck
CI95%: Confidence interval of 95%
Lower: Lower range of values with a 95% confidence interval
Upper: Upper range of values with a 95% confidence interval

The measurements for the neonatal cadavers in Group 1, as seen in Table 4.1, display an average length of the sternocleidomastoid muscle of 37.81mm (range: 35.09mm – 40.52mm). The nerve point is located 17.00mm (range: 14.89mm – 19.12mm) from the mastoid process and 20.80mm (range: 19.28mm – 22.32mm) from the clavicle.

In three bilaterally dissected neonatal cadavers (six dissections), the clavicles had been dislocated at either the sternoclavicular or acromioclavicular joint, resulting in an inability to accurately determine the length of the sternocleidomastoid muscle. Therefore, these six dissections were excluded for all measurements pertaining to the length of the sternocleidomastoid muscle.

4.4.1.2 Simulation on infant cadavers

The measurements for Group 2 (two infants between 28 days and one year of age) are presented in Table 4.2. However, the clavicle was dislocated in one cadaver, therefore all measurements related to the sternocleidomastoid muscle can only be reported for one infant cadaver, bilaterally dissected.

Table 4.2: Relationship between the superficial cervical plexus nerves emerging at the nerve point of the neck, and bony landmarks for infant cadavers (Group 2)

	Length SCM	**Distance MP - NP**	**Distance NP - Clavicle**
n	2	2	2
Mean	35.90	20.46	15.43
SD	4.01	0.34	4.35
CI95%	5.56	0.47	6.03
Lower	30.34	19.99	9.41
Upper	41.45	20.93	21.46

Key:

SCM: Sternocleidomastoid muscle
MP: Mastoid process
NP: Nerve point of the neck
CI95%: Confidence interval of 95%
Lower: Lower range of values with a 95% confidence interval
Upper: Upper range of values with a 95% confidence interval

From Table 4.2 it can be seen that in Group 2, the length of the sternocleidomastoid muscle could only be measured in one cadaver (bilateral dissections), due to the partial dislocation of the clavicle. The average length of the sternocleidomastoid muscle was 35.90mm (range: 30.34mm – 41.45mm). The nerve point was located 20.46mm (range: 19.99mm – 20.93mm) from the mastoid process and 15.43mm (range: 9.41mm – 21.46mm) from the clavicle.

4.4.2 Superficial cervical plexus to soft tissue landmarks

4.4.2.1 Nerve point of the neck to the midline

The measurements for the distance between the nerve point of the neck and the midline of the neck for Group 1 (22 cadavers) and Group 2 (two cadavers) are displayed in Table 4.3. For the neonatal cadavers, all 36 dissections contributed to the sample, while four dissections were used from two infant cadavers to obtain measurements.

Table 4.3: Distance of the nerve point of the neck to the midline for Group 1 and Group 2

	Group 1	**Group 2**
n	36	4
Mean	20.99	28.16
SD	5.55	7.37
CI95%	1.81	7.22
Lower	19.18	20.93
Upper	22.80	35.38

Key:

CI95%: Confidence interval of 95%
Lower: Lower range of values with a 95% confidence interval
Upper: Upper range of values with a 95% confidence interval

In Group 1, the nerve point of the neck is approximately 20.99mm (range: 19.18mm – 22.80mm) from the midline of the neck, and 28.16mm (range: 20.93mm – 35.38mm) on average for Group 2, as indicated in Table 4.3

The level at which the nerve point of the neck can be palpated in relation to the thyroid cartilage in the midline of the neck is represented in Table 4.4

Table 4.4: Level of the nerve point of the neck in relation to the thyroid cartilage for Group 1 and Group 2

	Group 1	**Group 2**
n	30	4
1	25	2
2	5	2

Key:

1: The nerve point corresponds to the superior border of the thyroid cartilage
2: The nerve point corresponds to the inferior border of the thyroid cartilage

The superior border of the thyroid cartilage corresponds to the level of the nerve point in 83.3% (25/30) of neonatal (Group 1) dissections, and in 50% (2/4) of the infant (Group 2) dissections. In Group 1, the nerve point of the neck corresponds to the inferior border of the thyroid cartilage in 16.6% (5/30) of the dissections and 50% (2/4) dissections for the infant cadavers in Group 2.

In three neonatal (Group 1) cadavers, the position of the nerve point relative to the thyroid cartilage in the midline could not be determined due to previous distortion of the midline structures. This resulted in the inability of accurately palpating the midline structures in order to determine the corresponding level of the nerve point. These three cadavers (six sets of measurements) were subsequently excluded from the data analysis.

4.4.2.2 Nerve point of the neck to the external jugular vein

The horizontal distance between the point where the superficial cervical plexus nerves emerge and the external jugular vein for the complete sample of 24 paediatric cadavers, subdivided into Group 1 and Group 2 respectively, are shown in Table 4.5.

Table 4.5: Distance between the nerve point of the neck and the external jugular vein for Group 1 and Group 2

	Group 1	**Group 2**
n	36	4
Mean	4.72	3.15
SD	3.62	2.04
CI95%	1.18	2.00
Lower	3.54	1.15
Upper	5.90	5.14

Key:

CI95%: Confidence interval of 95%
Lower: Lower range of values with a 95% confidence interval
Upper: Upper range of values with a 95% confidence interval

As seen in Table 4.5, the external jugular vein is on average 4.72mm (range: 3.54mm – 5.90mm) from the point where the superficial cervical plexus nerves emerge around the posterior border of the sternocleidomastoid muscle for Group 1, and 3.15mm (range: 1.15mm – 5.14mm) for Group 2.

The relationship between the transverse cervical nerve and the external jugular vein is presented in Table4.6 for the neonatal (Group 1) and infant (Group 2) cadavers.

Table 4.6: Relationship between the transverse cervical nerve and the external jugular vein for Group 1 and Group 2

	Group 1	**Group 2**
n	29	4
1	18	1
2	11	3

Key:

1: The transverse cervical nerve travels superficial to the external jugular vein
2: The transverse cervical nerve travels deep to the external jugular vein

In Group 1, the transverse cervical nerve travels superficial to the external jugular vein in 62.1% (18/29) of the dissections, and deep to the vein in 37.9% (11/29) of the dissections. In 25% (1/4) of cases of Group 2 cadavers, the transverse cervical nerve passes superficial to the external jugular vein, and in 75% (3/4), deep to the external jugular vein.

In seven neonatal (Group 1) dissections, the relationship between the transverse cervical nerve and the external jugular vein could not be determined due to the relationship being distorted. This occurred due to the most medial portion of the nerve either being damaged or loosely dissected, resulting in the inability to accurately identify the relationship.

4.4.3 Superficial cervical plexus nerve block in paediatric patients

The second aim of this research chapter entails the development of a standardised technique to easily and successfully block the superficial cervical plexus. This was done by means of measurements and observations on paediatric anatomical specimens.

4.4.3.1 The superficial cervical plexus nerve block in neonates

Due to the relatively small number of neonatal cadavers used, with unequal quantities between the left and the right side, the descriptive statistics for all measurements obtained from the right side of the cadavers are displayed in Table 4.7. Using only the measurements obtained from the right-sided dissections, a better correlation could be determined to the measurements obtained from the right hand of each cadaver.

Table 4.7: Descriptive statistics for measurements from dissections on right anterior-lateral cervical region for Group 1

	Length SCM	**Distance MP – NP**	**Distance NP – Clavicle**	**Distance NP – Midline**	**Distance NP – EJV**
n	16	19	16	19	19
Mean	39.15	18.01	20.78	21.89	5.38
SD	7.22	6.34	3.78	7.16	4.73
CI95%	3.54	2.85	1.85	3.22	2.13
Lower	35.61	15.15	18.92	18.67	3.26
Upper	42.68	20.86	22.63	25.11	7.51

Key:

SCM: Sternocleidomastoid muscle
MP: Mastoid process
NP: Nerve point of the neck
EJV: External jugular vein
CI95%: Confidence interval of 95%
Lower: Lower range of values with a 95% confidence interval
Upper: Upper range of values with a 95% confidence interval

As seen in Table 4.7, the average length of the sternocleidomastoid muscle on the right side of 16 neonatal cadavers was 39.15mm (range: 35.61mm – 42.68mm), while the distance from the nerve point to the clavicle was 20.78mm (range: 18.92mm – 22.63mm). The distance between the mastoid process and the nerve point on the right anterior-lateral cervical region had an average of 18.01mm (range: 15.15mm – 20.86mm), while the nerve point measured 21.89mm (range: 18.67mm – 25.11mm) on average from the midline. The average distance between the external jugular vein and the point where the superficial cervical plexus emerges cutaneously was 5.38mm (range: 3.26mm – 7.51mm).

In Table 4.8 the average measurements with regard to the fingers on the right hand for each of the neonates are presented.

Table 4.8: Average breadth of the fingers on the right hand for Group 1

	4 fingers	**3 fingers**	**2 fingers**	**1 finger**	**Thumb**
n	19	19	19	19	19
Mean	21.37	15.99	10.54	4.65	6.62
SD	6.22	4.45	2.98	1.19	3.83
CI95%	2.80	2.00	1.34	0.53	1.72
Lower	18.57	13.99	9.21	4.11	4.90
Upper	24.17	17.99	11.88	5.18	8.34

Key:

CI95%: Confidence interval of 95%
Lower: Lower range of values with a 95% confidence interval
Upper: Upper range of values with a 95% confidence interval

From Table 4.8 it can be seen that the average breadth of the four medial fingers at the proximal interphalangeal joint is 21.37mm (range: 18.57mm – 24.17mm) and 15.99mm (range: 13.99mm – 17.99mm) for the medial three fingers. The breadth for the medial two fingers is 10.54mm (range: 9.21mm – 11.88mm) and for the pinkie it is 4.65mm (range: 4.11mm – 5.18mm) at the proximal interphalangeal joint. The breadth of the thumb at the interphalangeal joint measured an average of 6.62mm (range: 4.90mm – 8.34mm).

In order to accurately evaluate the correlations between the breadth of the fingers on the right hand of each cadaver for Group 1 to the distances displayed in Table 4.7, population correlation coefficients were determined and are displayed in Table 4.9.

Table 4.9: Pearson correlation coefficient values for Group 1

	4 fingers	**3 fingers**	**2 fingers**	**1 finger**	**Thumb**
Length SCM (R-value)	0.49	0.53	0.52	**0.72**	0.64
p-value	0.0566	0.0344	0.0371	0.0016	0.0076
Distance MP – NP (R-value)	0.43	0.54	0.54	**0.61**	0.17
p-value	0.0653	0.0168	0.0171	0.0055	0.4978
Distance NP – Clavicle (R-value)	0.14	0.03	-0.01	0.21	**0.18**
p-value	0.6138	0.9187	0.9791	0.4319	0.4973
Distance NP – Midline (R-value)	0.64	0.74	**0.75**	0.42	0.13
p-value	0.0031	0.0003	0.0002	0.0757	0.6057
Distance NP – EJV (R-value)	0.13	0.20	0.18	**0.28**	-0.09
p-value	0.6044	0.4206	0.4597	0.2479	0.7251

Key:

SCM: Sternocleidomastoid muscle
MP: Mastoid process
NP: Nerve point of the neck
EJV: External jugular vein

From Table 4.9 it is evident that no positive correlation (> 0.80) exists between the distances obtained in aim (a) and observed in Table 4.7, and the breadth of the fingers on the right hand of each cadaver. The distance between the nerve point of the neck and the midline correlates well with the medial two fingers, with a Pearson correlation coefficient of 0.75. However, this is below the threshold of this research study.

4.4.3.2 The superficial cervical plexus nerve block in infants

Unfortunately, only one of the two infant cadavers, which were dissected for the superficial cervical plexus nerve block, had a right hand available to obtain measurements from. The upper limbs of the other cadaver were removed from the trunk in a previous research study. Thus, no descriptive statistics could be obtained on the breadth of the proximal interphalangeal joints of the right hand.

To evaluate whether a positive correlation exists between the breadths of the fingers on the right hand of each infant, and the distances ascertained in aim (a), population correlations coefficients needed to be determined. However, due to only one set of variables with regard to the measurements on the hand being available, the Pearson correlation coefficients could not be determined for Group 2.

4.5 Discussion

The cervical plexus consists of the anterior rami of C1 – C4, that form an irregular series of nerve loops. Each ramus, except the first, branches into ascending and descending branches which reunite to form the loops (Mousel, 1941; Moore *et al.,* 2014). The cervical plexus is located anteromedial to the levator scapulae and middle scalene muscles, and deep to the sternocleidomastoid muscle. It consists of deep (motor) branches and superficial (sensory) branches. “The cutaneous branches of the cervical plexus emerge around the middle of the posterior border of the sternocleidomastoid muscle, often called the nerve point of the neck” (Moore *et al.,* 2014).

The cutaneous terminal branches of the cervical plexus are the lesser occipital, great auricular, transverse cervical and suprascapular nerves (Tran *et al.,* 2010; Herring *et al.,* 2012). These superficial sensory branches innervate the skin and superficial structures located in the anteromedial cervical region, as well as sections of the ear and the shoulder (Herring *et al.,* 2012).

In adults, the superficial cervical plexus nerve block is most commonly indicated for:

- Carotid endarterectomy (Stoneham *et al.,* 1998; Merle *et al.,* 1999; Stoneham and Knighton, 1999: Pandit *et al.,* 2000; Pandit *et al.,* 2003; Gomes *et al.,* 2010; Ramachandran *et al.,* 2011; Vaniyapong *et al.,* 2013; Pasin *et al.,* 2015; Alilet *et al.,* 2016; Kavakli *et al.,* 2016);
- Thyroid surgery (Mousel, 1941; Saxe *et al.,* 1988; Yerzingatsian, 1989; Dieudonne *et al.,* 2001; Aunac *et al.,* 2002; Andrieu *et al.,* 2007; Herlich, 2012; Egan *et al.,* 2013; Karthikeyan *et al.,* 2013);
- Parathyroid surgery (Saxe *et al.,* 1988; Herlich, 2012; Egan *et al.,* 2013; Su *et al.,* 2015).

In the paediatric population, thyroid surgeries are performed using the superficial cervical plexus nerve block (Dieudonne *et al.,* 2001; Aunac *et al.,* 2002; Voronov and Suresh, 2008; Roberts and Cowen, 2016), while surgeries involving the ears, such as mastoidectomy and otoplasty (Suresh, 2003), tympanomastoid surgery (Suresh *et al.,* 2002; Suresh *et al.,* 2004), as well as bilateral simultaneous cochlear implantation (Merdad *et al.,* 2012), are also performed using regional anaesthesia involving the superficial cervical plexus.

Suresh and co-workers (2002) emphasize that postoperative pain is often treated with opioids, which results in adverse effects such as nausea and vomiting. Tympanomastoid surgery can also result in the occurrence of nausea and vomiting after the surgery. “Therefore, methods to provide analgesia while avoiding or reducing the need for opioids may help decrease postoperative opioid-associated morbidity” (Suresh *et al.,* 2002). Peripheral nerve blocks are used to effectively achieve analgesia without the incidence of adverse effects caused by systemic medications (Roberts and Cowen, 2016).

The posterior border of the sternocleidomastoid muscle is the most commonly referred to landmark when blocking the superficial cervical plexus in both adults and children (Tobias, 1999; Merle *et al.,* 1999; Suresh, 2003; Voronov and Suresh, 2008; Merdad *et al.,* 2012; Suresh and Voronov, 2012; Su *et al.,* 2015; Roberts and Cowen, 2016). However, the techniques for approaching this landmark, as well as the exact level of the injection site, differ vastly. Suresh and Voronov (2012) state that the greater auricular nerve hooks around the belly of the sternocleidomastoid muscle at the level of the hyoid prominence, while Merdad *et al.* (2012) and Alilet *et al.* (2016) report that the midpoint of the sternocleidomastoid muscle can be found at the C3 - C4 vertebral level.

Proper needle location (Alilet *et al.,* 2016), as well as intravascular injection (Suresh and Wheeler, 2002) and increased systemic absorption (Merle *et al.,* 1999), are complications and difficulties experienced during the performance of the superficial cervical plexus nerve block. However, the author believes that, should an easily performed technique be well described, following meticulous measurements and research, the challenges and difficulties encountered can be reduced and the superficial cervical plexus can be effectively anaesthetised in the paediatric population.

4.5.1 The relationship of the superficial cervical plexus to bony landmarks

In order to easily and effectively block the superficial cervical plexus in the paediatric population, a clear and easy to perform approach needs to be developed, based on clear anatomical descriptions. This can be achieved by measuring the distances between the superficial cervical plexus and specific bony landmarks.

4.5.1.1 Simulation on neonatal cadavers

The measurements of the superficial cervical plexus to bony landmarks for neonates are presented in Table 4.1. The sternocleidomastoid mastoid muscle measured an average length of 37.81mm (range: 35.09mm – 40.52mm). The cutaneous branches of the superficial cervical plexus emerge from the posterior border of the sternocleidomastoid muscle at a distance of 17.00mm (range: 14.89mm – 19.12mm) from the mastoid process and 20.80mm (range: 19.28mm – 22.32mm) from the clavicular attachment.

Our results compare well to the study conducted by Gupta and co-workers (2013) where the nerve point of the neck was evaluated in South Indian foetuses. In the group of foetuses ranging from 13 – 24 weeks of gestation, the nerve point was located 18.5mm (range: 14mm – 27mm) from the clavicle on the right side and 18.5mm (range: 11mm – 29mm) on the left side. In the foetuses 25 – 38 weeks of gestation, the nerve point was located 26.7mm (range: 15mm – 33mm) from the clavicle on the right side and 26.2mm (range: 18mm – 34mm) on the left.

Gupta and co-workers (2013) also measured the nerve point from the external acoustic meatus. They determined that for the first group, the distances ranged from 16mm – 27mm (average of 20.6mm) on the right side and 15mm – 25mm (average of 18.5mm) on the left side. For the second group (25 – 38 weeks), the nerve point was located 23.2mm (range: 21mm – 26mm) from the external acoustic meatus on the right side and 20.8mm (range: 14mm – 28mm) on the left side. Although the measurements in their study were obtained between the nerve point and the external acoustic meatus, a good comparison, with a small difference ranging from 1.5mm to 6.2mm, is observed between the study by Gupta *et al.* (2013) and this study.

When the distance between the mastoid process and the nerve point is expressed as a ratio of the length of the sternocleidomastoid muscle, the value is 44.96%. This indicates that the nerve point is located close (slightly superior) to the midpoint on the posterior border of the sternocleidomastoid muscle, as seen in Figure 4.2.

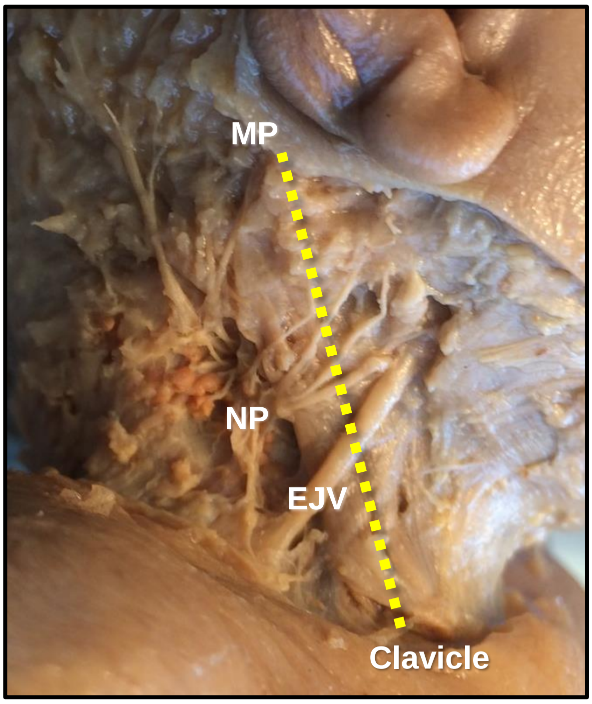


Figure 4.2: The nerve point located at the posterior border of the sternocleidomastoid muscle in the neonatal population
[MP – Mastoid process; NP – Nerve point; EJV – External jugular vein]

This is in accordance with statements made by Tobias (1999) and Merdad *et al.* (2012), that the superficial cervical plexus is approached at the midpoint of the posterior border of the sternocleidomastoid muscle.

4.5.1.2 Simulation on infant cadavers

Two infant cadavers were dissected in order to evaluate the superficial cervical plexus. The acquired results are presented in Table 4.2. However, due to the clavicle being dislocated in one of the specimens, the nerve point could only be effectively evaluated bilaterally in one infant cadaver. The sternocleidomastoid muscle measured an average length of 35.90mm (range: 30.34mm – 41.45mm), while the nerve point exhibited a distance of 20.46mm (range: 19.99mm – 20.93mm) from the mastoid process and 15.43mm (range: 9.41mm – 21.46mm) from the clavicle.

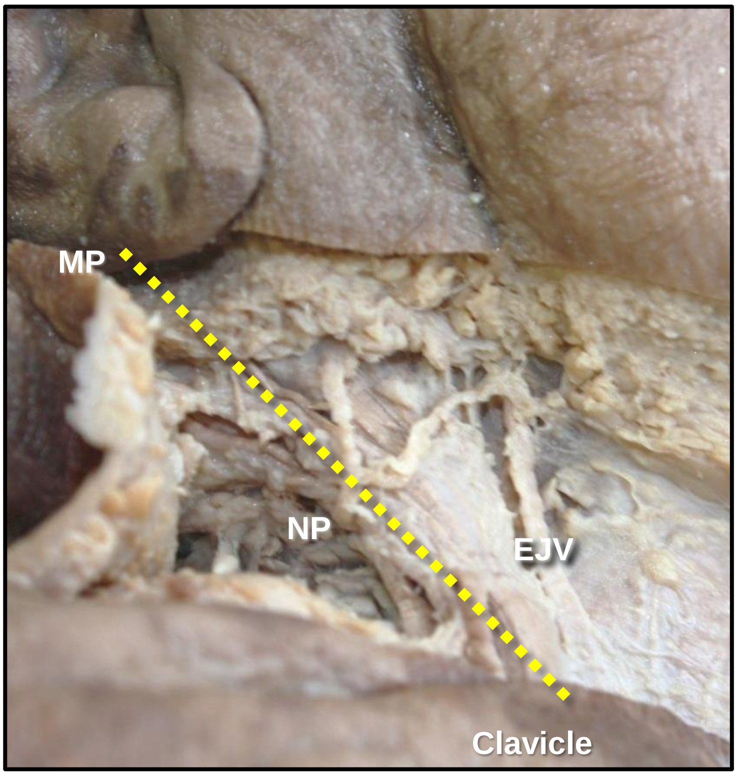


Figure 4.3: The nerve point located at the posterior border of the sternocleidomastoid muscle in the infant population
[MP – Mastoid process; NP – Nerve point; EJV – External jugular vein]

The obtained distances correspond well to the method used by Andrieu and authors (2007), where the efficacy of a bilateral superficial cervical plexus block was determined. In their study, the needle was inserted 2cm above the clavicle along the posterior border of the clavicular head of the sternocleidomastoid muscle. Although this method was performed on adult patients, a positive comparison can be made with regard to the ascertained distances.

Should a ratio be calculated based on the results of the one infant cadaver, the distance between the nerve point of the neck and the mastoid process is 56.99% of the length of the sternocleidomastoid muscle. As seen in Figure 4.3, the nerve point is located near the midpoint of the posterior border of the sternocleidomastoid muscle.

Similar to the results obtained in the neonatal sample, the cutaneous branches of the cervical plexus emerge around the posterior border of the sternocleidomastoid muscle, near the midpoint. This corresponds to the description of the nerve point of the neck by Moore and Dalley (2006), which states that the nerve point is located in the middle of the posterior border of the sternocleidomastoid muscle. This is the point where the branches of the superficial cervical plexus become cutaneous.

4.5.2 Relationship of the superficial cervical plexus to soft tissue landmarks

Through clear descriptions of easily identifiable anatomical landmarks, head and neck blocks can be safely accomplished in children (Voronov and Suresh, 2008). Therefore, the sensory cutaneous branches of the cervical plexus were evaluated in relation to soft tissue landmarks.

4.5.2.1 Nerve point of the neck to the midline

The distance between the nerve point of the neck and the midline of the neck of 22 neonatal cadavers (Group 1) and two infant cadavers (Group 2) is displayed in Table 4.3. The nerve point of the neck is located 20.99mm (range: 19.18mm – 22.80mm) and 28.16mm (range: 20.93mm – 35.38mm) from the midline of the neck on average, for Group 1 and Group 2, respectively.

By reviewing scientific articles using Google scholar and scientific databases such as Ovid, Pubmed or Medline, as well as several anatomical textbooks, the distance between the nerve point of the neck and the midline has not yet been documented or described. Therefore, according to the researcher, this is the first description of this distance, especially in the paediatric population. This distance will further assist practising anaesthesiologists to successfully establish the location of the superficial cervical plexus.

In addition, the exact level of the nerve point of the neck was evaluated in relation to the thyroid cartilage in the midline, as seen in Table 4.4 and in Figure 4.4.

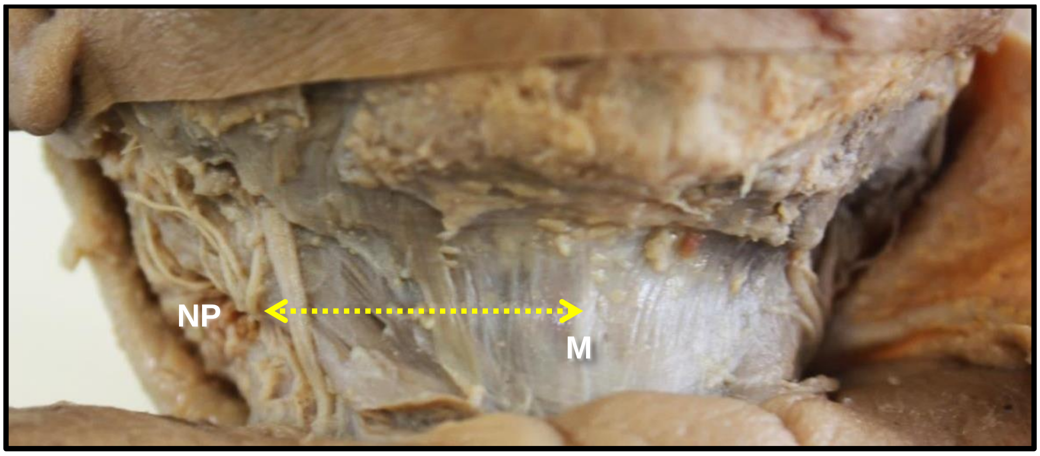


Figure 4.4: The nerve point of the neck in relation to the midline of the neck, in the neonatal population
[NP – Nerve point; M – Midline of the neck]

In neonates (Group 1) the nerve point corresponds to the superior border of the thyroid cartilage in 83.3% of the dissections and 16.6% to the inferior border of the thyroid cartilage. For the infant group (Group 2) the nerve point is palpated at the level of both the superior border and the inferior border of the thyroid cartilage in 50% of the cases.

In the adult population, the nerve point of the neck is located either at vertebral level C3 (Dieudonne *et al.,* 2001; Tubbs *et al.,* 2005), C3 - C4 (Alilet *et al.,* 2016), C4 transverse processes (Kavakli *et al.,* 2016), or the cricoid cartilage (Herring *et al.,* 2012).

In the paediatric population, Merdad *et al.* (2012), as well as Tobias (1999), described a superficial cervical plexus block at the landmark corresponding to C3 - C4, while Suresh and Voronov (2006), Belvis *et al.* (2007) and Suresh and Voronov (2012) used the level of C6. Several research papers describe the injection point for blocking either the entire superficial cervical plexus or one of its branches, the great auricular nerve, at the level of the cricoid cartilage (Suresh and Wheeler, 2002; Suresh *et al.,* 2004; Voronov and Suresh, 2008).

In the literature, the similarity between the nerve point and the midline is either described according to the vertebral levels, or the midline structures. In order to accurately compare the obtained literature to the results of this study, the midline structures are linked to the vertebral levels. According to the well-known anatomical textbook Gray's Anatomy by Standring (2008), the superior border of the thyroid cartilage corresponds to the junction between the C3 and C4 vertebrae, with the hyoid bone located at C3 and the cricoid cartilage at C6. Clinically Oriented Anatomy by Moore and Dalley (2014) links the superior border of the thyroid cartilage to C4 vertebra and the cricoid cartilage to C6.

This study is, therefore, in agreement with the paediatric research papers of Tobias (1999), as well as Merdad *et al.* (2012), and also the adult population studies of Dieudonne *et al.* (2001), Tubbs *et al.* (2005), Alilet *et al.* (2016), and Kavakli *et al.* (2016), that associate the level of the emergence of the superficial cervical plexus branches around the posterior border of the sternocleidomastoid muscle with the superior border of the thyroid cartilage.

4.5.2.2 Nerve point of the neck to the external jugular vein

When performing any nerve block near vital structures, special attention needs to be placed on possible complications that could occur. Due to the neck being extremely vascular, accidental injection of local anaesthetic into the jugular veins could result in systemic toxicity. Haematomas could also develop should a vessel be torn or punctured (Suresh *et al*., 2002). Therefore, the distances between the external jugular vein and the cutaneous branches of the cervical plexus were measured, and are displayed in Table 4.5.

The external jugular vein is located approximately 4.72mm (range: 3.54mm – 5.90mm) from the nerve point in neonates (Group 1) and 3.15mm (range: 1.15mm – 5.14mm) in the infant cadavers (Group 2). This indicates a very close relationship between the location where the cutaneous branches of the cervical plexus will be anaesthetised and the external jugular vein, as seen in Figure 4.5.

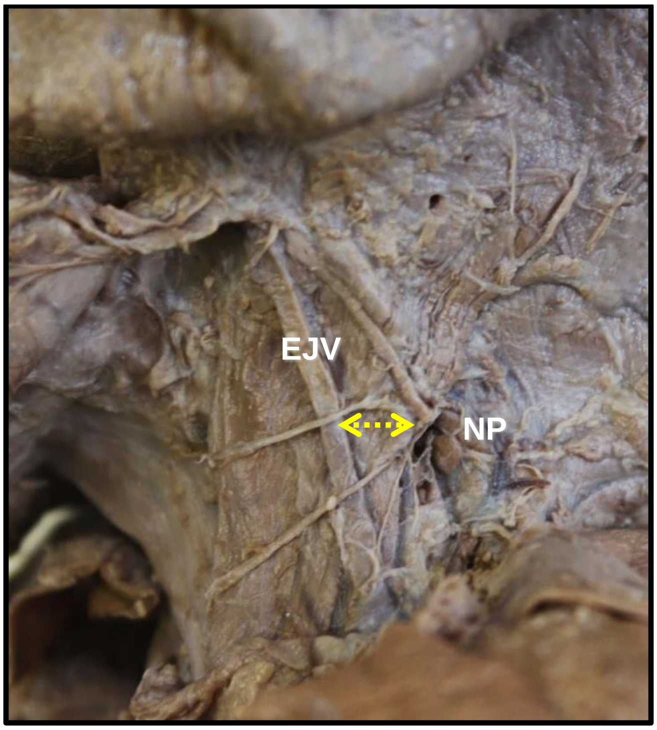


Figure 4.5: The distance between the external jugular vein and the nerve point in the left cervical region of a neonate
[EJV – External jugular vein; NP – Nerve point]

In a study published by Castro in 2001, the exact relationship between the external jugular vein and the great auricular nerve was evaluated. He states: “Since the great auricular nerve is always located behind the external jugular vein at an average distance of 1.5cm and at a maximum distance of 2cm, it is the most easily identifiable anatomic structure in this region.”

McKinney and Katrana (1980) concluded in their study that the great auricular nerve is situated dorsally to the external jugular vein at a distance of 0.5cm, while Murphy *et al.* (2012) indicate that the great auricular nerve can reliably be found between 0.79 and 1.56cm posterior to the external jugular vein.

Although all of the aforementioned studies were conducted on adult specimens, the close relationship between the superficial cervical plexus branches, emerging around the posterior border of the sternocleidomastoid muscle, and the external jugular vein should be noted.

The transverse cervical nerve and external jugular vein relationship is shown in Table 4.6. For the neonatal cadavers (Group 1), the transverse cervical nerve passes over the external jugular vein in 62.1% of cases and deep to the vein in 37.9% of the dissections. In one of the four (25%) infant cadavers (Group 2), the transverse cervical nerve passes superficial to the external jugular vein and deep to the vein in the remaining three cadavers (75%).

Ramachandran and co-workers (2011) mention in their research study that the cutaneous cervical nerve passes deep to the external jugular vein on its way to the anterior border of the sternocleidomastoid muscle. Even though this is not similar to the observations made in this research study, knowledge of the relationship between the superficial cervical plexus and the closely associated vascular structures will assist in the prevention of puncture-related complications.

4.5.3 Superficial cervical plexus nerve block in paediatric patients

The superficial cervical plexus nerve block is a safe and easy to perform technique to ensure that the patient is pain free (Mariappan *et al*., 2015). In a study conducted by Tran *et al.* (2010), the efficacy of the superficial cervical plexus nerve block, executed using ultrasound, and a landmark-based technique are compared. They conclude that no difference in success rate between the two approaches was encountered and attribute this event to the ease with which the superficially located branches can be blindly anaesthetised. Yet, a standardised method to block the superficial cervical plexus, which is acquired from paediatric anatomical dissections, is required to minimise possible complications.

4.5.3.1 The superficial cervical plexus nerve block in neonates

In order to formulate a standardised method to block the superficial cervical plexus in the neonates, only the measurements obtained from the right side of the cadavers are displayed in Table 4.7.

The nerve point was located 20.78mm (range: 18.92mm – 22.63mm) from the clavicle and 18.01mm (range 15.15mm – 20.86mm) from the rudimentary mastoid process. The average length of the sternocleidomastoid muscle from its distal attachment on the clavicle to its proximal attachment on the mastoid process, measured 39.15mm (range: 35.61mm – 42.68mm). The nerve point is located 21.89mm (range: 18.67mm – 25.11mm) from the midline, and 5.38mm (range: 3.26mm – 7.51mm) from the external jugular vein.

In order to attempt simplifying the approach to the superficial cervical plexus, the average breadth of the fingers on the right hands of each cadaver in Group 1 was measured and is recorded in Table 4.8. The medial four fingers presented with an average breadth at the proximal interphalangeal joint of 21.37mm (range: 18.57mm – 24.17mm), while the medial three and medial two fingers displayed an average breadth of 15.99mm (range: 13.99mm – 17.99mm) and 10.54mm (range: 9.21mm – 11.88mm), respectively. The breadth of the pinkie at the proximal interphalangeal joint was 4.65mm (range: 4.11mm – 5.18mm) and the interphalangeal breadth of the thumb was 6.62mm (range: 4.90mm – 8.34mm).

The measurements obtained from the landmark measurements were correlated with the breadths of the fingers on the right of each cadaver, as seen in Table 4.9. In order to undoubtedly state that a landmark distance correlates to a specific fingerbreadth measurement, a Pearson correlation coefficient threshold of 0.80 is set for this research study.

No positive correlation coefficient ($R > 0.80$) could be found for the measurements obtained in the neonatal cadaver sample. Although the distance between the midline and the nerve point of the neck exhibited a Pearson correlation coefficient of 0.75, this falls below the threshold of this research study.

4.5.3.2 The superficial cervical plexus nerve block in infants

In order to accurately evaluate the presence of a positive correlation in the infant cadavers, two sets of variables need to be compared with each other. However, due to the small sample size for the infant cadavers, and the dislocation of the upper limbs of one cadaver, measurements on the right hand fingerbreadth of the only remaining cadaver could be obtained. This resulted in the inability to draw parallels between the distances of the landmarks and the breadths of the fingers on the right hand for the infant cadavers in Group 2.

4.6 Limitations of this study and proposed future research

The following limitations on this part of the research study were been identified and are proposed for future research studies:

1. A significant limitation of this component of the research study is the small infant population sample. In order to evaluate the superficial cervical plexus nerve block in infant cadavers more accurately, more detailed dissections on infant cadavers are proposed. Yet, the scarcity of infant cadavers reiterates the value of any data obtained from paediatric cadavers.

2. Due to torsion of the cervical region of some cadavers, the superficial cervical plexus could not be evaluated bilaterally. This challenge can be addressed by dissecting fresh frozen cadaveric specimens. However, these are not easily obtainable. Despite a lack of bilaterally dissected superficial cervical plexus nerves in paediatric cadavers, the knowledge acquired through the performed dissections will greatly benefit and assist practising anaesthesiologists during the administration of this nerve block in paediatric patients.

4.7 Conclusion

The superficial cervical plexus nerve block is performed in the paediatric population in various settings, which include different ear and neck surgeries (Dieudonne *et al.,* 2001; Suresh *et al.,* 2002; Suresh, 2003; Merdad *et al.,* 2012; Murphy *et al.,* 2012; Karthikeyan *et al.,* 2013; Su *et* al., 2015; Kavakli *et al*., 2016). This nerve block can either be performed as a single block, or in conjunction with other peripheral nerve blocks (Suresh *et al.,* 2002; Suresh, 2003; Suresh and Voronov, 2012). Through anatomical dissections of paediatric cadavers, this study attempted to equip medical professionals with more accurate and paediatric applicable information, which could result in better outcomes of the superficial cervical plexus nerve block.

In the paediatric population, the superficial cervical plexus can be anaesthetised posterior to the external jugular vein, at the midpoint of the sternocleidomastoid muscle, which corresponds to the superior border of the thyroid cartilage.

4.8 References

Alilet, A; Petit, P; Devaux, B; Joly, C; Samain, E; Pili-Floury, S; Besch, G. (2016) Ultrasound-guided intermediate cervical block versus superficial cervical block for carotid artery endarterectomy: The randomized-controlled CERVECHO trial. *Anaesth Crit Care Pain Med*. Published online 29 July 2016

Andrieu, G; Amrouni, H; Robin, E; Carnaille, B; Wattier, JM; Pattou, F; Vallet, B; Lebuffe, G. (2007) Analgesic efficacy of bilateral superficial cervical plexus block administered before thyroid surgery under general anaesthesia. *Br J Anaesth* 99: 561 – 566

Aunac, S; Carlier, M; Singelyn, F; De Kock, M. (2002) The analgesic efficacy of bilateral combined superficial and deep cervical plexus block administered thyroid surgery under general anesthesia. *Anesth Analg* 95(3): 746 – 750

Bagul, A; Taha, R; Metcalfe, MS; Brook, NR: Nicholson, ML. (2005) Pre-Incision infiltration of local anesthetic reduces postoperative pain with no effects on bruising and wound cosmesis after thyroid surgery. *Thyroid* 15(11): 1245 – 1248

Belvis, D; Voronov, P; Suresh, S. (2007) Head and neck blocks in children. *Tech Reg Anesth Pain Manag* 11: 208 – 214

Castro, C. (2001) Anatomic Study of the Relationships Between the External Jugular Vein, the Greater Auricular Nerve and the Platysma Muscle. *Rev Bras Cir Plast* 12(3): 29 – 36

Chow, TL; Choi, CY; Lam, SH. (2013) Parotidectomy under local anesthesia – report of 7 cases. *Am J Otolaryngol* 34: 79 – 81

Dieudonne, N; Gomola, A; Bonnichon, P; Ozier, YM. (2001) Prevention of postoperative pain aftetr thyroid surgery: a double-blind randomized study of bilateral superficial cervical plexus blocks. *Anesth Analg* 92: 1538 – 1542

Egan, RJ; Hopkins, JC; Beamish, AJ; Shah, R; Edwards, AG; Morgan, JDT. (2013) Randomized clinical trial of intraoperative superficial cervical plexus block versus incisional local anaesthesia in thyroid and parathyroid surgery. *Br J Anaesth* 100: 1732 – 1738

Ella, B; Lanqbour, N; Caix, P; Midy, D; Deliac P; Burbaud, P. (2015) Transverse cervical and great auricular nerve distribution in the mandibular area: a study in human cadavers. *Clin Anat* 28 (1): 109 – 117

Eti, Z; Irmak, P; Gulluoglu, BM; Manukyan, MN; Gogus, FY. (2006) Does bilateral superficial cervical plexus block decrease analgesic requirement after thyroid surgery? *Anest Analg* 102: 1174 – 1176

Goktas, U; Isik, Y; Kati, I; Aytekin, OC; Bartin, S. (2013) Bilateral superficial and deep cervical plexus block for thyroidectomy in pregnancy. *Int J Obstet Anesth* 22(2): 171

Gomes, M; Soares, MO; Dumville, JC; Lewis, SC; Torgerson, DJ; Bodenham. AR; Gough, MJ; Warlow, CP; GALA Collaborative group. (2010) Cost-effectiveness analysis of general anaesthesia versus local anaesthesia for carotid surgery (GALA Trail). *Br J Surg* 97: 1218 – 1225

Gupta, C; D’Souza, AS; Ray, B. (2013) Anatomical variations in the emergence of the cutaneous nerves from the nerve point in the neck and identification of the landmarks to located the nerve point with its clinical implications: a cadaveric study on South Indian Human Foetuses. *J Clin Diagn Res* 7(3): 413 – 417

Herring, AA; Stone, MB: Frenkel, O; Chipman, A; Nagdev, AD. (2012) The ultrasound-guided superficial cervical plexus block for anesthesia and analgesia in emergency care settings. *Am J Emerg Med* 30: 1263 – 1267

Herlich, A. (2012) Focused local anesthesia and analgesia for head and neck surgery. *International anesthesiology clinics* 50(1): 13 – 25

Kanawati, S; Fawal, H; Maaliki, H; Naja, ZM. (2015) Laparoscopic sleeve gastrectomy in five awake obese patients using paravertebral and superficial cervical plexus blockade. *Anaesthesia 70*(8): 993 – 995

Karthikeyan, VS; Sistla, SC; Badhe, AS; Mahalakshmy, T; Rajkumar, N; Ali, SM; Gopalakrishnan, S. (2013) Randomized controlled trial on the efficacy of bilateral superficial cervical plexus block in thyroidectomy. *Pain Pract* 13(7): 539 – 546

Kavaklı, AS; Öztürk, NK; Ayoğlu, RU; Sağdıç, K; Çakmak, G; İnanoğlu, K; Emmiler, M. (2016) Comparison of Combined (Deep and Superficial) and Intermediate Cervical Plexus Block by Use of Ultrasound Guidance for Carotid Endarterectomy. *J Cardiothorac Vasc Anesth* 30(2): 317 – 322

Lee, KS; Davis CH; McWhorter, JM. (1988) Low morbidity and mortality of carotid endarterectomy performed with regional anesthesia. *J Neurosurg* 69: 483 – 487

Mariappan, R; Mehta, J; Massicotte, E; Nagappa, M; Manninen, P; Venkatraghavan, L. (2015) Effect of superficial cervical plexus block on postoperative quality of recovery after anterior cervical discectomy and fusion: a randomized controlled trial. *Can J Anaesth* 62(8): 883 – 890

Matsunami, S; Komasawa, N; Fujiwara, S; Fujitate, Y; Soen, M: Minami, T. (2015) Anesthetic management using frontal nerve, greater occipital nerve and superficial cervical plexus block for posterior cervical spinal fusion in a patient with athetoid cerebral palsy. *Masui* 64(5): 549 – 551

McKinney, P; Katrana, DJ. (1980) Prevention of injury to the great auricular nerve during rhytidectomy. *Plast Reconst Surg* 66(5): 675 – 679

Merdad, M; Crawford, M; Gordon, K; Papsin, B. (2012) Unexplained fever after bilateral superficial cervical block in children undergoing cochlear implantation: an observational study. *Can J Anesth* 59: 28 – 33

Merle, JC; Mazoit, JX; Desgranges, P; Abhay, K; Rezaiguia, S; Dhonneur, G; Duvaldestin, P. (1999) A comparison of two techniques for cervical plexus blockade: evaluation of efficacy and systemic toxicity. *Anest Analg* 89: 1366 – 1370

Moore, KL; Dalley, AF. (2006) Clinically oriented anatomy. 5th edition. Lippincott Williams & Wilkins. Chapter 8, p 1053

Moore, KL; Dalley, AF, Agur, AMR. (2014) Clinically oriented anatomy. 7th edition (electronic version). Lippincott, Williams & Wilkins. p1509

Mousel, LH. (1941) Regional anesthesia for operations about the head and neck. *Anesthesiology* 2(1): 61 – 73

Murphy, R; Dziegielewski, P; O'connell, D; Seikaly, H; Ansari, K; Peuker, ET; Filler, TJ; Lindsay, JT; McKinney, P; Katrana, DJ; Izquierdo, R. (2012) The great auricular nerve: an anatomic and surgical study. *Otolaryngol Head Neck Surg* 41(1): 75 – 77

Pandit, JJ; Bree, S; Dillon, P; Elcock, D; McLaren, ID; Crider, B. (2000) A comparison of superficial versus combined (superficial and deep) cervical plexus block for carotid endarterectomy: a prospective, randomized study. *Anesth Analg* 91: 781 – 786

Pandit, JJ; Dutta, D; Morris, JF. (2003) Spread of injectate with superficial cervical plexus block in humans: an anatomical study. *Br J Anaesth* 91(5): 733 – 735

Pandit, JJ; Satya-Krishna, R; Gration, P. (2007) Superficial or deep cervical plexus block for carotid endarterectomy: a systematic review of complications†. *Br J Anaesth* 99(2): 159 – 169

Pasin, L; Nardelli, P; Landoni, G; Cornero, G; Magrin, S; Tshomba, Y; Chiesa, R; Zangrillo, A. (2015) Examination of regional anesthesia for carotid endarterectomy. *J Vasc Surg* 62(3): 631 – 634

Pillay, P; Partab, P; Lazarus, L; Satyapal, KS. (2012) The great auricular nerve in foetuses. *Int J Morphol* 30(1): 40 – 44

Ramachandran, SK; Picton, P; Shanks, A; Dorje, P; Pandit, JJ. (2011) Comparison of intermediate vs subcutaneous cervical plexus block for carotid endarterectomy. *Br J Anaesth* 107(2): 157 – 163

Roberts, S; Cowen, R. (2016) Peripheral and local anaesthetic techniques for paediatric surgery. *Anaesth Int Care Med* 17(6): 286 – 292

Saxe, AW; Brown, E; Hamburger, SW. (1988) Thyroid and parathyroid surgery performed with patient under regional anesthesia. *Surgery* 103(4): 415 – 420

Standring, S. (2008) Gray's anatomy. 40th edition. The anatomical basis of clinical practice. Churchill, Livingstone, Elsevier. Chapter 28, p 435 – 436, 440 – 441; 455 – 457

Stoneham, MD; Doyle, AR; Knighton, JD; Dorje, P; Stanley, JC. (1998) Prospective, randomized comparison of deep or superficial cervical plexus block for carotid endarterectomy surgery. *Anesthesiology* 89(4): 907 – 912

Stoneham, MD; Knighton, JD. (1999) Regional anaesthesia for carotid endarterectomy. *Br J Anaesth* 82: 910 – 919

Su, Y; Zhang, Z; Zhang, Q; Zhang, Y; Liu, Z. (2015) Analgesic efficacy of bilateral superficial and deep cervical plexus block in patients with secondary hyperparathyroidism due to chronic renal failure. *Ann Surg Treat Res* 89(6): 325 – 329

Suresh, S. (2003) Practical pediatric regional anesthesia. *ASA Refresher Courses in Anesthesiology* 31(1): 177 – 190

Suresh, S; Barcelona, S; Young, N; Seligman, I; Heffner, CL; Coté, CJ (2002) Postoperative pain relief in children undergoing tympanomastoid surgery: Is a regional block better than opioids? *Anest Analg* 94: 859 - 862

Suresh, S; Barcelona, SL; Young, NM; Heffner, CL; Cote, CJ (2004) Does a preemptive block of the great auricular nerve improve postoperative analgesia in children undergoing tympanomastoid surgery? *Anest Analg* 98: 330 – 333

Suresh, S; Bellig, G. (2004) Regional anesthesia in a very low-birth-weight neonate for a neurosurgical procedure. *Reg Anesth Pain Med* 29: 58 – 59

Suresh, S; Voronov, P. (2006) Review article. Head and neck blocks in children: an anatomical and procedural review. *Ped Anesth* 16: 910 – 918

Suresh, S; Voronov, P. (2012) Review article. Head and neck blocks in infants, children, and adolescents. *Ped Anesth* 22: 81 – 87

Suresh, S; Wheeler, M. (2002) Practical pediatric regional anesthesia. New concepts and techniques in pediatric anesthesia: Volume 20, Number 1, (March) of Anesthesiology Clinics of North America. Linda J Mason and Michelle S Kim, editors Darien, Illinois: WB Saunders Company. p 83 - 113

Tobias, JD. (1999) Cervical plexus block in adolescents. *J Clin Anesth* 11: 606 – 608

Tran, DQ; Dugani, S; Finlayson, RJ. (2010) A randomised comparison between ultrasound-guided and landmark-based superficial cervical plexus block. *Reg Anesth Pain Med* 35(6): 539 – 543

Tubbs, RS; Salter, EG; Oakes, WJ. (2005) Anatomic landmarks for nerves of the neck: A vade mecum for neurosurgeons. *Neurosurgery* 56: 256 – 260

Tubbs, RS; Salter, EG; Wellons, JC; Blount, JP; Oakes, WJ. (2007) Landmarks for the identification of the cutaneous nerves of the occiput and nuchal regions. *Clin Anat* 20: 235 – 238

Vaniyapong, T; Chongruksut, W; Rerkasem, K. (2013) Local versus general anaesthesia for carotid endarterectomy. *The Cochrane Library*. John Wiley and Sons, Ltd.

Voronov, P; Suresh, S. (2008) Head and neck blocks in children. *Curr Opin Anaesthesiol* 21: 317 – 322

Yerzingatsian, KL. (1989) Thyroidectomy under local analgesia: the anatomical basis of cervical blocks. *Ann R Coll Surg Engl* 71: 207 – 210

5 Greater occipital nerve block

5.1 Introduction

The greater occipital nerve is derived from the posterior ramus of the cervical nerve root C2 (Vital *et al*., 1989; Suresh and Wheeler, 2002; Suresh and Voronov, 2006; Tubbs *et al.,* 2007; Greher *et al.,* 2010; VanderHoek *et al.,* 2013). This nerve provides cutaneous innervation to most of the posterior scalp or occipital area (Bogduk, 1982; Ward, 2003; Henderson, 2009; Osborn and Sebeo, 2010; Suresh and Voronov, 2012). Levin (2009) reports that this nerve innervates the scalp portion located between the external occipital protuberance and the vertex.

Ward (2003) states: “It originates deep to the oblique inferior [capitis] muscle where a communicating branch from the third cranial nerve may join the greater occipital nerve.” This is most likely a typing error and the author referred to the posterior ramus of the third cervical nerve, as indicated by Gawel and Rothbart (1992).

The greater occipital nerve emerges in the posterior neck, after passing lateral to the atlanto-axial joint (Vital *et al*., 1989; Ward, 2003; Osborn and Sebeo, 2010), below the posterior arch of the atlas (Greher *et al.,* 2010).

Vital and colleagues (1989), as well as Gille *et al.* (2004), extensively explain the course of the greater occipital nerve, indicating that this nerve consists of three parts and two bends:

- The first part travels obliquely downwards and in a posterior-lateral direction to reach the inferior border of the inferior oblique capitis muscle;
- The first bend occurs at the point where the nerve passes around the muscle and starts travelling in an upwards and anteromedial direction;
- The second part of the nerve travels between the semispinalis capitis muscle superficially, and the deep inferior oblique capitis, rectus capitis posterior and rectus capitis anterior muscles;

- The second bend occurs where the nerve crosses the semispinalis capitis muscle, passing through the muscle fibres to emerge near the midline;
- The third part is the portion where the nerve travels supero-laterally between the semispinalis capitis and trapezius muscles. Dissections of these muscle revealed that this portion of the nerve passes through the tendinous part of the trapezius muscle to become subcutaneous.

Tubbs and co-workers (2007) are in accordance with the abovementioned statements, reporting that the nerve passes between the inferior oblique capitis and semispinalis capitis muscles, ascending and piercing both the semispinalis capitis and trapezius muscles. Greher and colleagues (2010) agree by stating that this nerve hooks around the lower border of the inferior oblique capitis muscle and travels superiorly over this muscle across the roof of the suboccipital triangle.

Ducic and co-authors (2009) reaffirm the course of the greater occipital nerve by mentioning that it travels between the inferior oblique and semispinalis capitis muscles. It then crosses over the rectus capitis posterior major muscle and emerges medial to the semispinalis capitis muscle, which is occasionally pierced by this nerve. The greater occipital nerve then pierces the trapezius muscle to emerge with the occipital artery. However, there are anatomical variations in its course.

Dash and co-workers (2005) dissected 20 fresh human cadaveric heads and located the greater occipital nerve bilaterally in 19 of their specimens. In all 38 dissections the greater occipital nerve pierced the semispinalis capitis muscle. Similarly, in a study conducted by Mosser *et al.* (2004), the greater occipital nerve pierced the semispinalis capitis in all 40 of their dissections of 20 fresh cadaveric heads.

In a study conducted by Vital and co-workers in 1989, the dissections of 19 posterior rami of the second cervical nerve in nine formalin-embalmed adult cadavers showed that in 13 cases the nerve passed through the aponeurotic opening of the trapezius muscle, prior to dividing into its terminal branches. In five cases the nerve had already divided into its terminal branches before emerging from this opening. However, all the branches emerged through the same opening onto the posterior scalp. In only one case did the medial branch appear through a separate opening.

Ducic and co-workers (2009) state that the greater occipital nerve pierces the trapezius muscle at the level of the inion (external occipital protuberance). Levin (2009) describes this point as being located approximately one-third of the distance, on a line drawn from the external occipital protuberance to the mastoid process.

Ward (2003) mentions that the greater occipital nerve becomes subcutaneous just inferior to the superior nuchal line, by traveling above an aponeurotic sling which consists of inserting fibres of both the trapezius and sternocleidomastoid muscles. Suresh and Wheeler (2009) also refer to the aponeurotic sling just below the superior nuchal line through which the nerve travels to pass medial to the occipital artery.

In the literature, the consensus is that the occipital artery lies lateral to the greater occipital nerve (Polaner *et al.,* 2000; Suresh and Wagner, 2001; Ward, 2003; Henderson, 2009; Greher *et al.,* 2010; Osborn and Sebeo, 2010; VanderHoek *et al.,* 2013). Due to the close proximity of the greater occipital nerve and the occipital artery, special consideration needs to be taken on the exact point of infiltration of the anaesthetic fluid.

Based on the close relationship between the occipital artery and the greater occipital nerve, the artery can be palpated in order to locate the greater occipital nerve (Henderson, 2009; Levin, 2009). It is important to note that the nerve is initially located medial to the artery; however, at the level of the superior nuchal line, the artery is located medial to the nerve (Suresh and Voronov, 2012).

In two separate publications by Janis and co-workers (2010a and b), the exact relationship between the occipital artery and the greater occipital nerve was evaluated in 25 fresh cadaveric heads. In the first study (2010a), the authors concluded that the greater occipital nerve has six compression points, of which one is the vascular point, where the occipital artery either crosses, compresses or is intertwined with the nerve. In the second study (2010b), a relationship between the artery and the nerve was reported in 54% of the cases. Of these, 70.4% demonstrated a helical intertwining with several twists between the structures, while 29.6% exhibited a single intersection. This is vital to note in the blocking of the greater occipital nerve, since the assumption cannot be made that the artery is always located lateral to the nerve.

Great variations exist with the description on the location and route of the greater occipital nerve, as indicated above, with little to no description on paediatric patients. On the surgical importance of the greater occipital nerve, Ducic and co-workers (2009) state: “The clinical relevance of their surgical anatomy has increased drastically over the past several years as surgical decompression of these nerves and preoperative nerve blocks have become used increasingly for the treatment of chronic occipital headaches.” Therefore, it is important to establish a standard that can be used in surgical settings, specifically applicable to paediatric patients.

5.1.1 Indications

In adults, the foremost indication for the use of the greater occipital nerve block relates to pain relief in headache disorders, such as:

- Migraine (Caputi and Firetto, 1997; Austad, 2004; Ashkenazi and Young, 2005; Dash *et al.,* 2005; Janis *et al.*, 2010a; Gelfand *et al.,* 2014);
- Cervicogenic headache (Bovim and Sand. 1992; Caputi and Firetto, 1997; Inan *et al.,* 2001; Naja *et al.,* 2006; Levin, 2009; Tobin and Flitman, 2009);
- Cluster headaches (Peres *et al.,* 2002; Ambrosini *et al.,* 2005; Afridi *et al.,* 2006; Busch *et al.,* 2007; Tobin and Flitman, 2009; Lambru *et al.,* 2013);
- Occipital neuralgia (Dugan *et al.,* 1962; Ward, 2003’ Loukas *et al.,* 2006; Natsis *et al.,* 2006; Levin, 2009; Tobin and Flitman, 2009; Eldrige *et al.,* 2010; VanderHoek *et al.,* 2013);

- Short-lasting unilateral neuralgiform headache with conjunctival injection and tearing syndrome (Choi *et al.,* 2012).

Migraine is a common neurovascular disorder (Ashkenazi *et al.,* 2008) that can be so severe that it prevents the patient from partaking in activities (Janis *et al.*, 2010a). Migraines are often encountered in paediatric patients and can greatly impair their performance at school (Arruda and Bigal, 2012). Lipton and co-workers (2011) report that 0.8 – 1.75% of adolescents, 12 – 17 years of age, experience chronic migraine, while Arruda and Bigal (2012) conclude that 0.6%, 17.6% and 9% of children between the ages 5 – 12, experience chronic, probable and episodic migraines respectively.

Levin (2009) defines cervicogenic headache as head pain referring from the cervical region, with evidence of a cervical spinal lesion, which can be eliminated should neural blockade of the cervical pain generator be performed. Naja and co-workers (2006) report that the blocking of the greater occipital nerve is also used in the diagnosis of cervicogenic headaches.

Ambrosini and co-workers (2005) state that cluster headache is one of the most disabling forms of headache, while occipital neuralgia can be described as chronic occipital headaches that can be triggered by irritation or trauma to the greater occipital nerve (VanderHoek *et al.,* 2013). Local anaesthesia of the greater occipital nerve can either be used in the diagnosis or treatment of pain generated by the greater occipital nerve (Greher *et al.,* 2010).

Occipital neuralgia, also called “neuritis”, is characterised by stabbing pain in the distribution area of the greater occipital nerve that results in tenderness in the area of this nerve. The tenderness is reduced by the performance of a local block of the greater occipital nerve (Levin, 2009), or by applying pressure over the course of the greater or lesser occipital nerves (Vanelderen *et al.,* 2010).

Post-traumatic headache can also be relieved by a greater occipital nerve block (Szabova *et al.,* 2012). Seeger and co-workers (2015) ratify that posttraumatic headaches in children with occipital tenderness can be effectively treated with an occipital nerve block. Watson and Leslie (2001) report that the greater occipital nerve block provides adequate analgesia for the placement of a stereotactic frame, as compared to subcutaneous infiltration.

During craniotomies, several anaesthetic techniques can be used for analgesic purposes. However, according to Nguyen and co-workers (2001), as well as Osborn and Sebeo (2010), a more commonly performed method is the 'scalp block', which involves anaesthesia of all the nerves that supply the scalp. They summarise that the forehead and anterior scalp is supplied by the supraorbital and supratrochlear nerves, while the greater occipital nerve is responsible for most of the posterior scalp. Bala and co-workers (2006) confirm through their study that a scalp block decreases the frequency, as well as the severity, of postoperative pain in patients undergoing a supratentorial craniotomy. This research will greatly assist surgeons and anaesthesiologists who prefer to use the 'scalp block' for craniotomies, especially in paediatric patients.

In the paediatric population greater occipital nerve blocks are used in providing pain relief for occipital neuralgia, as well as posterior fossa craniotomies (Ward, 2003; Suresh and Voronov, 2006). For occipital craniotomies and posterior shunt revisions, a greater occipital nerve block will also be utilised for occipital pain relief (Suresh and Voronov, 2006; Henderson, 2009). In the study conducted by Hartley and co-workers (1991), they conclude that the mean arterial pressure and heart rate of children undergoing craniotomies, decreased due to scalp infiltration, indicating the effectiveness and advantages of regional nerve blocks.

Suresh and Wheeler (2002) state that blocking the greater occipital nerve provides ipsilateral analgesia for paediatric patients undergoing occipital incisions, including craniotomies for posterior fossa tumours and posterior ventriculo-peritoneal shunts. Anaesthesia for the excision of skin lesions on the scalp of patients can also be achieved by a greater occipital nerve block (Suresh *et al.,* 2002; Suresh and Wagner, 2001).

In a case report, Suresh and Bellig (2004) successfully administered peripheral nerve blocks (supraorbital, great auricular and greater occipital) to an 18-day-old, 700g critically ill neonate, who underwent an Ommaya reservoir placement for hydrocephalus. They state: “The peripheral nerve blocks provided excellent postoperative analgesia as indicated by stable vital signs in the entire postoperative period.” Therefore, this research will greatly assist medical professionals in the successful administration of these regional nerve blocks, specifically in the paediatric population.

5.1.2 Contra-indications

Contra-indications for the use of peripheral nerve blocks include local infection, coagulopathy, or the parents and / or child’s opposition (Suresh and Wheeler, 2002).

A study conducted by Leroux and co-workers (2011) focused on administering suboccipital steroid injections targeted at the greater occipital nerve for the treatment of cluster headaches in adults. Patients suffering from any bleeding disorder, or who were on anticoagulant therapy, were excluded from the study, due to the possible development of a hematoma.

Sprenger and Seifert (2013) described a case where a patient went into a coma shortly after receiving a greater occipital nerve block for unilateral facial pain. The patient’s medical history indicated a previous posterior fossa craniotomy. They deduced that a detailed patient history needs to be obtained, and that previous posterior fossa craniotomies are an absolute contra-indication in the performance of greater occipital nerve blocks. Okuda and co-authors (2001) reported the loss of consciousness in a patient after the administration of a lesser occipital nerve block. They determined that the patient had a bone defect due to a previously performed craniotomy, and therefore also contra-indicate occipital nerve blocks in the presence of bone defects.

5.1.3 Step-by-step procedure

Even though several adult studies have been conducted on the greater occipital nerve and the use of local anaesthetics, very little information could be obtained about the origin of the standards used on paediatric patients.

Several methods of locating the greater occipital nerve are currently being used in adult patients:

- Palpation of the occipital artery
    - Janis and co-workers (2010b) evaluated the intersection between the occipital artery and the greater occipital nerve and concluded that the mean location of the artery-nerve intersection was at a single point intersection. This point is located 30.27mm ± 6.83mm lateral to the midline, and 10.67mm ± 8.25mm caudal to the external occipital protuberance. In the cases where more than one intersection was identified, the range extended from 25.34mm ± 12.16mm to the midline and 24.91mm ± 12.87mm caudal to the protuberance for the most caudal part of the helical intertwining, up to 42.09mm ± 25.61mm from the midline and 0.97mm ± 8.34mm caudal to the external occipital protuberance.
    - The occipital artery is located lateral to the greater occipital nerve at the superior nuchal line. The pulsation of the artery at this point is easy to palpate (Ward, 2003).
    - Henderson (2009) states that the occipital artery can be palpated at the level of the superior nuchal line. The greater occipital nerve is located medial to the artery.
    - The occipital artery is located on a line connecting the greater occipital tubercle with the mastoid prominence, and the greater occipital nerve can be blocked medial to the artery (Herlich, 2012).
    - VanderHoek and co-workers (2013) state that the occipital artery can be palpated on the posterior aspect of the head at the level of the inion, or slightly inferior.

- Point between mastoid process and external occipital protuberance
    - The greater occipital nerve is located approximately two-thirds of the distance on a line drawn between the mastoid process and external occipital protuberance (Levin, 2009). In a similar description, Ashkenazi and co-workers (2008; 2010) report that the greater occipital nerve is located at a point lateral to the inion, one third of the distance between the external occipital protuberance and the mastoid process.
    - The greater occipital nerve is located on the superior nuchal line, one third of the distance between the external occipital protuberance and the mastoid process (Watson and Leslie, 2001; Costello and Cormack, 2004).
    - Several studies report the technique where a line is drawn between the mastoid process and the inion. The needle is inserted at the point corresponding to the junction of the medial and middle thirds of the line (Leroux *et al.,* 2001; Lambru *et al.,* 2013).
    - The greater occipital nerve is located midway between the occipital protuberance and the mastoid process, 25mm lateral to the nuchal median line (Osborn and Sebeo, 2010).
    - The site for blocking the greater occipital nerve is located on the nuchal line, halfway between the mastoid process and the occipital protuberance (Pinosky *et al.,* 1996; Busch *et al.,* 2005; Bala *et al.,* 2006).
    - In the study by Ambrosini and authors (2005), the greater occipital nerve was blocked in the suboccipital fossa midway between the inion and the mastoid process.
    - When using a nerve stimulator, the greater occipital nerve was located 3 – 12mm medial to the midpoint of the line connecting the occipital protuberance and the mastoid process (Anthony, 2000).
    - The nerve is found 10 – 20mm below the midpoint between the mastoid process and the occipital tubercle (Afridi *et al.,* 2006).

- External occipital protuberance as reference point
    - "Injecting approximately 20mm lateral to the external occipital protuberance is a useful approach" (Levin, 2009). This point was also used in the study by Ashkenazi and Young (2005).
    - Using a nerve stimulator, Naja and co-workers (2006) located the greater occipital nerve 25mm below the external occipital protuberance.
    - According to Loukas and co-authors (2006), the location of the greater occipital nerve has been established as being one thumb's breadth lateral to the external occipital protuberance (20mm laterally) and approximately at the base of the thumb nail (20mm inferior to the external occipital protuberance). Several other studies also reported utilising the point 20mm lateral and 20mm inferior to the external occipital protuberance (Bovim and Sand, 1992; Caputi and Firetto, 1997; Inan *et al.,* 2001).
    - Vital and co-workers (1989) conclude from their study that the point where the greater occipital nerve emerges from the trapezius muscle is located 23 – 38mm lateral and 15 – 32mm inferior to the external occipital protuberance.
    - In one of the largest published reports on the anatomy of the greater occipital nerve, Ducic and co-workers (2009) found that the nerve emerges from the semispinalis capitis muscle on average 14.9 ± 4.5mm lateral to the midline, and 30.2 ± 5.1mm caudal to the external occipital protuberance. The nerve then pierces the fascia of the trapezius muscle 37.8 ± 4.6mm from the external occipital protuberance.
    - In the treatment of a short-lasting unilateral neuralgiform headache with conjunctival injection and tearing syndrome, Choi and authors (2012) blocked the greater occipital nerve 20mm inferior and 25mm lateral to the external occipital protuberance.
    - Vanelderen and colleagues (2010) infiltrated the greater occipital nerve at a point 31.8mm lateral and 22.2mm inferior to the external occipital protuberance.

    - The greater occipital nerve can be specifically located 11.8mm from the midline on the right and 11.0mm on the left, 27mm inferior to the external occipital protuberance on the right and 26mm on the left (Dash *et al.,* 2005).

- Reference point in relation to semispinalis capitis muscle
    - Injections can be administered 20 - 25mm inferior to the external occipital protuberance and 15mm lateral to the midline. This will ensure that the greater occipital nerve is blocked at the location where it pierces the semispinalis capitis muscle (Natsis *et al.,* 2006).
    - Tubbs and co-workers (2007) mention that the greater occipital nerve can be found 40mm lateral to the external occipital protuberance and 20mm superior to the intermastoid line where it pierces the semispinalis capitis muscle.
    - The greater occipital nerve emerges from underneath the semispinalis muscle, 30mm inferior to the occipital protuberance and 15mm lateral to the midline (Mosser *et al.,* 2004).

- Other landmarks
    - Greher *et al.* (2010) conducted a study comparing two techniques of blocking the greater occipital nerve. The classic block site (medial to the occipital artery at the superior nuchal line) was compared to the site where the nerve crosses over the inferior oblique capitis muscle. However, the last site was under ultrasound guidance during the performance of this nerve block.
    - Becser and co-workers (1998) suggest that the intermastoid line be used as landmark, since it is generally easy to define. The greater occipital nerve should be blocked at more than one site along this line, approximately between 15 – 25mm from the midline.

The following techniques have been described for the location of the greater occipital nerve in paediatric patients:

- Occipital artery
    - The occipital artery can be located slightly lateral to the midline, inferior to the superior nuchal line. The greater occipital nerve is initially located medial to the artery. However, it can later be observed more laterally (Suresh and Voronov, 2012).
    - Henderson (2009), as well as Suresh and Wagner (2001), palpate the occipital artery at the level of the superior nuchal line, and then locate the medially placed greater occipital nerve.
    - The occipital artery can be palpated inferior to the external occipital protuberance. The needle is placed next to the artery and in the subcutaneous plane while fanning laterally (Suresh and Voronov, 2006).
    - Szabova *et al.* (2012) state: “Injections can be done in a fan-like manner, infiltrating subcutaneous tissues medially and laterally to the occipital artery.”
    - The occipital artery is palpated at the level corresponding to the superior nuchal line, and subcutaneous fanning is performed (Suresh and Wheeler, 2002).

- Other landmarks
    - Suresh and Voronov (2012) also stated: “The midpoint of a line drawn between the mastoid process and the midline will be a good guide to the location of the greater occipital nerve.” However, they do not state whether this line is drawn in a cranial, caudal or horizontal direction from the mastoid process.
    - In a study on occipital nerve blocks for paediatric posttraumatic headaches, Seeger and co-workers (2015) used the landmark 20mm lateral and 20mm inferior to the external occipital protuberance, as well as palpation, to determine the area of greatest point tenderness as their injection point.

- Hartley and authors (1991) used scalp infiltration in paediatric patients undergoing brain surgery by infiltrating the solution subcutaneously along the incision line.
- "The clinician palpated over the greater occipital nerves and injected the side that was most tender" (Gelfand *et al.,* 2014).

Greher and co-workers (2010) state: "Although easily performed, the classical method of injecting 'blindly' just medial to the palpated occipital artery at the level of the superior nuchal line is not target specific". Due to the close proximity of additional nerves and the higher volumes of anaesthetic fluid required because of blind injection, complications such as unspecific analgesic effects due to anaesthetic spread, could occur.

Even though several different techniques can be used to block the greater occipital nerve, a standardised technique based on the anatomical dissection of the greater occipital nerve and the related landmarks needs to be evaluated for paediatric patients.

5.1.4 Anatomical pitfalls

The biggest anatomical pitfalls acquired from the literature are related to the lack of standard technique, as well as the lack of a specific known location of the greater occipital nerve and possible variations with regard to the nerve and its relationship to the occipital artery.

According to Ashkenazi and co-authors (2010), Bovim and colleagues (1991), as well as Becser *et al.* (1998), report that the occipital artery has a high variability in relation to the greater occipital nerve. In the study conducted by Becser and co-workers (1998), the greater occipital nerve was investigated bilaterally in 10 embalmed cadavers (thus 20 samples). In 12 cases, the winding occipital artery was very closely related to a nerve network formed by the greater occipital nerve.

Janis and colleagues (2010b) conducted an extensive study on the relationship between the occipital artery and the greater occipital nerve. A total of 25 fresh heads were dissected bilaterally. A close relationship between these two structures was observed in 54% of cases. In 70.4% of the cases, there was a helical type of intersection resulting in several twists between the structures, while in 29.6% of cases, a single intersection was observed.

The close relationship between the occipital nerve and the occipital artery needs to be noted and emphasized, since the close proximity of these structures can result in complications experienced.

Ducic and co-workers (2009) emphasize that the increased targeting of occipital nerves in therapeutic and diagnostic methodologies, improved accuracy and appreciation of the variations related to the nerves, can improve treatment results, as well as diagnostic precision.

Suresh and Voronov (2006) make the following statement: “A thorough understanding of the anatomy of the area will allow the paediatric anaesthesiologist to appreciate the ease with which one can provide analgesia without the added side effects of opioid analgesia”. A detailed anatomical description of the greater occipital nerve and related landmarks in a paediatric population will greatly reinforce the previous statement.

5.1.5 Complications and side-effects

Ward (2003) states: “There are relatively few complications because of the superficial location of the nerve. However, intravascular injection is a possibility.” The greater occipital nerve is closely related to the occipital artery, after piercing the trapezius muscle (Tubbs *et al.,* 2007). Natsis and co-workers (2006) conclude that their findings correlate to several other studies, where the greater occipital nerve and the occipital artery both pierce the aponeurosis of the trapezius muscle, either separately, or apart. If aspiration is not performed, intravascular injection of the occipital artery could occur, even though this is a rare occurrence.

Even though a greater occipital nerve block can be easily performed, Greher and co-workers (2010) mention that injecting the anaesthetic solution ‘blindly’ after palpating the occipital artery, is not target specific. This often results in higher volumes of anaesthetic agent being used, which could result in unspecific analgesic effects due to additional nerves being blocked by the spread of the increased anaesthetic fluid. Due to excessive doses of local anaesthetic, systemic toxicity could occur due to the increased plasma levels (Ashkenazi *et al.,* 2010).

Lavin and Workman (2001) reported a case where a female patient, who was treated with bilateral greater occipital nerve blocks for chronic migraines over a period of three months, developed clear signs of Cushing syndrome. These symptoms were accompanied with sporadic hypertension, severe muscle weakness, fluid retention, centripetal obesity, moon facies (or moon face), a dorsal fat pad and pharyngitis, even though they state that candida and herpes simplex could have contributed to certain of the adverse effects. They conclude that patients receiving repetitive occipital nerve blocks with corticosteroids should be closely monitored.

Other complications and side effects listed in the literature are often limited to a small number of patients:

- In a study conducted by Afridi *et al.* (2006), a single vaso-vagal syncopal attack was encountered during the blocking of the greater occipital nerve, while three patients complained of dizziness.
- Two cases of alopecia (hairloss) and cutaneous atrophy around the injection site were observed by Shields and co-workers (2004).
- Busch and co-authors (2007) reported that one patient experienced hypoaesthesia or numbness of the entire trigeminal nerve on the ipsilateral side of the face, lasting approximately four days.
- Loss of consciousness due to an occipital bone defect in a patient receiving an occipital nerve block, was reported by Okuda and colleagues (2001).
- In a study on the treatment of cervicogenic headache, Anthony (2000) states that the most common side effects following the injection was the perceived sensation of “fullness” in the occipital region, lasting two to

three days. Eight patients reported dizziness and uncertainty of gait for 22 to 48 hours following the steroid injection.

In the paediatric population, the following side effects and complications have been reported:

- In a study conducted by Seeger and co-workers (2015) on occipital nerve blocks for paediatric posttraumatic headaches, one patient developed a small area of alopecia.
- During the administration of greater occipital nerve injections in paediatric patients, 38% of the patients recorded temporary tingling and / or numbness in the distribution area of the nerve after the injection (Gelfand *et al.,* 2014).
- Suresh and Voronov (2006, 2012) affirm that complications are rare. However, intravascular injection could occur, should an incorrect technique be used. This can be avoided by careful aspiration (Suresh and Wheeler, 2002; Suresh and Voronov, 2006).
- "Though complications are rare, it is important to note the proximity to the spinal canal. Particular caution should be exercised in patients who have had surgery to the posterior fossa" (Suresh and Wheeler, 2002).
- Szabova *et al.* (2012) list possible side effects as alopecia, skin infections, as well as inflammation. Seizures could also occur, should the local anaesthetic and / or glucocorticoid be injected intravascularly. They also mention that the most severe complication that could occur, is intracerebral injection that will require immediate seizure control and possible resuscitation.

Suresh and Voronov (2012) state that these nerve blocks are sensory in nature and can therefore be easily performed with minimal side effects. However, a basic understanding of the relevant anatomy of the distribution of these sensory nerves are needed for the accurate performance and understanding of these nerve blocks. A thorough anatomical study investigating these nerves, directions of travel, as well as the relationships to additional landmarks are required, in order to assist the practising anaesthesiologist with the safe and effective practice of regional nerve blocks, especially in the paediatric population.

5.2 Aims

The following aims will be addressed in this research chapter:

5.2.1 To provide a detailed description of the course of the greater occipital nerve as it travels towards the occipital area of the head, with measurements to related anatomical structures and easily palpatable landmarks.

5.2.2 To evaluate the relationship between the greater occipital nerve and the occipital artery.

5.2.3 To formulate a standardised method of blocking the greater occipital nerve in a paediatric population.

5.3 Materials and Methods

5.3.1 Cadaveric dissections

a. To provide a detailed description of the course of the greater occipital nerve as it courses towards the occipital area of the head, with measurements to related anatomical structures and easily palpatable landmarks.

In order to determine the course and relationship of the greater occipital nerve to relevant landmarks, the occipital region of 41 paediatric cadavers was dissected bilaterally to effectively visualise and measure the greater occipital nerve, as seen in Figure 5.1. None of these cadavers were dissected in the occipital region prior to this research study.

The cadavers were placed in the prone position and the occipital region was dissected bilaterally. A skin flap was created and reflected laterally. The soft tissue was removed to expose the trapezius muscle and its aponeurosis, as well as the greater occipital nerve and the occipital artery.

The following bony and soft tissue landmarks were identified and used to take measurements:

- A – The greater occipital nerve;
- B – External occipital protuberance;
- C – Mastoid process;
- D – Midline of the neck;
- E – Occipital artery.

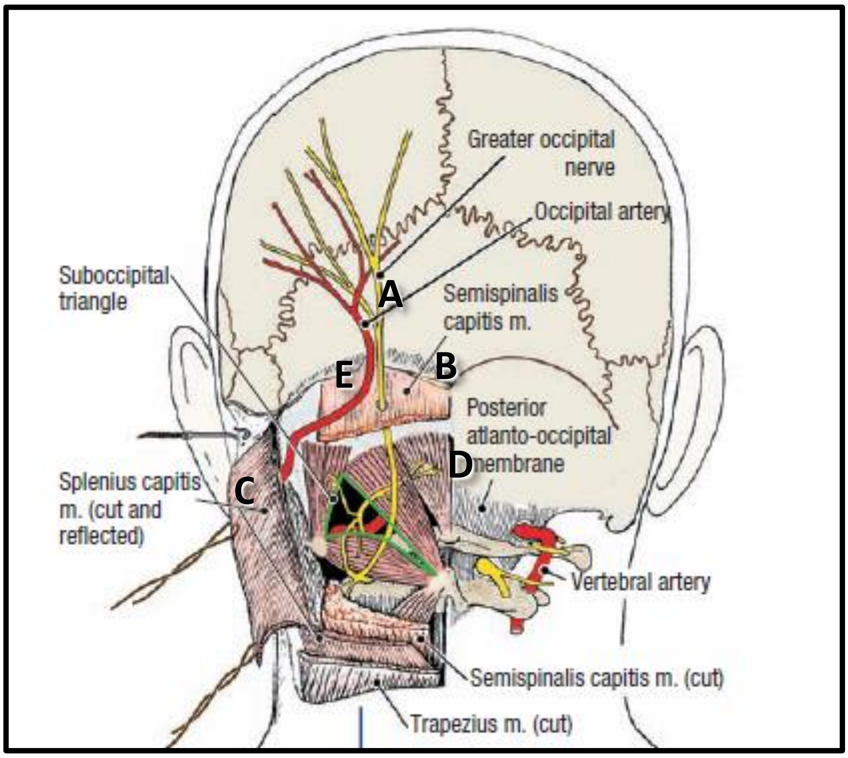


Figure 5.1: Illustration of the course of the greater occipital nerve and the occipital artery through the occipital region (Tank, 2013)

In order to find the exact location where the greater occipital nerve emerges as a cutaneous branch onto the scalp, the relationship between the nerve and other landmarks were determined bilaterally on the dissected cadavers:

- The distance between the greater occipital nerve (A) and the external occipital protuberance (B);
- The distance between the external occipital protuberance (B) and the mastoid process (C), measured in a straight line.

These measurements were used to determine whether an exact point for blocking the greater occipital nerve in the paediatric population could be determined.

These measurements will assist the researcher in establishing a more accurate location for blocking the greater occipital nerve in the classical method, as used in the adult population. The fixed landmarks will assist practitioners to perform this nerve block with greater ease and fewer complications.

b. To evaluate the relationship between the greater occipital nerve and the occipital artery.

The occipital artery is found lateral to the greater occipital nerve in the occipital region (Polaner *et al.,* 2000; Suresh and Wagner, 2001; Ward, 2003; Henderson, 2009; Greher *et al.,* 2010; Osborn and Sebeo, 2010; VanderHoek *et al.,* 2013). Janis *et al.* (2010b) stated that the occipital artery lies in close relationship to the greater occipital nerve in 54% of their dissected cadaveric specimens.

In order to effectively describe the location of the greater occipital nerve in the occipital region, the relationship between the greater occipital nerve (A) and the occipital artery (E) was evaluated in a paediatric population, as illustrated Figure 5.1. This was achieved by dissecting the occipital artery as it passes through the trapezius muscle and its aponeurosis. The exact relationship between these structures was described by observing and measuring the following:

- The relation of the occipital artery to the greater occipital nerve as either being medial or lateral;
- The distance between the occipital artery and the greater occipital nerve as they exist the trapezius muscle aponeurosis.

The description of the greater occipital nerve and the occipital artery will ensure that adequate information on the exact relationship and location of these two structures, applicable to a paediatric population sample, is available. This will provide a better knowledge base with subsequent fewer complications.

c. To formulate a standardised method of blocking the greater occipital nerve in a paediatric population.

The results obtained in (a) and (b), as well as all the techniques obtained from the literature, were compared and analysed to determine a standardised method of blocking the greater occipital nerve in paediatric patients.

The distance between the greater occipital nerve and fixed landmarks will assist clinicians and anaesthesiologists performing this technique on paediatric patients. To further facilitate the calculation, the breadth of the fingers on the right hand of each cadaver was measured as follows:

- Breadth of the medial four fingers at the proximal interphalangeal joint;
- Breadth of the medial three fingers at the proximal interphalangeal joint;
- Breadth of the medial two fingers at the proximal interphalangeal joint;
- Breadth of the 5th digit / digitus manus minimus (little finger) at the proximal interphalangeal joint;
- Breadth of the thumb at the interphalangeal joint.

In order to facilitate performing practitioners to easily determine the correct distances that need to be used, a correlation between the distances obtained in (a) and the breadth of the fingers on the right hand of each cadaver was determined. This will aid in the estimation of the relevant distances, without having to use a measuring device, in order to accurately block the greater occipital nerve.

5.3.2 Statistical analysis

In order to accurately compare the obtained results, the sample was divided into two age groups:

- Group 1 consisted of neonatal cadavers (0 - 28 days after birth);
- Group 2 included infant cadavers between 28 days and one year of age.

After precision dissections on 41 paediatric cadavers which included 35 neonatal cadavers and six infant cadavers, measurements were obtained using a Vernier digital calliper (accuracy of 0.01mm). All the measurements obtained were captured in a MS Excel data sheet, in order to complete statistical analysis of the acquired data.

The obtained measurements of the distance between the greater occipital nerve and the occipital artery were analysed for descriptive statistics using SAS® version 9.3, for Windows, which includes:

- The mean or average of each measurement;
- The standard deviation in order to establish the range of the sample;
- 95% confidence interval to establish the true population value for the statistic value, including upper and lower ranges.

All measurements were collected bilaterally. A paired T-test was done to determine whether any significant differences existed between the right and the left sides. A p-value of <0.05 was regarded as statistically significant.

Statistically comparing the qualitative observations between the neurovascular structures and depicting the averages, allowed for the determination of the exact relationship of the greater occipital nerve and the occipital artery. This was the second aim of the research chapter.

The best method of blocking the greater occipital nerve was attained by means of statistical comparison of the data using SAS® version 9.3, for Windows, which included:

- The mean or average of each measurement;
- The standard deviation in order to establish the range of the sample;
- 95% confidence interval to establish the true population value for the statistic value, including upper and lower ranges.

The third aim of this study was to formulate a standardised method of blocking the greater occipital nerve in a paediatric population. This was achieved by determining the exact location of the greater occipital nerve.

One of the most common methods of locating the greater occipital nerve is through the use of the external occipital protuberance / inion and the mastoid process. The relationship between the distance from external occipital protuberance to the mastoid process, and the distance from the external occipital protuberance to the greater occipital nerve was determined by establishing a ratio between the previously mentioned measurements.

In order to facilitate the establishment of the technique, the distances and information obtained in the first and second aims were used and compared to the breadth of the fingers on the right hand of each individual cadaveric specimen. This correlation was determined by a using Pearson population correlation coefficient to determine the relationship between the two sets of variables. A correlation coefficient of greater than 0.80 was considered as a positive relationship between the two sets of variables.

5.4 Results

5.4.1 Measurements for the greater occipital nerve block

The first aim of this study was to provide a detailed description, with measurements to related anatomical structures and easily palpatable landmarks, of the course of the greater occipital nerve as it travels towards the occipital area of the head.

As calculated in Chapter 1, no statistically significant difference was observed between the left and right side measurements obtained from the cadavers. Therefore, all measurements of the right and left sides were combined as the total sample.

5.4.1.1 Simulation on neonatal cadavers

The bilateral measurements for Group 1 (35 neonates, 0 - 28 days after birth) are summarised in Table 5.1.

Table 5.1: Neonatal cadavers of Group 1

	Distance EOP - MP	**Distance GON - EOP**
N	70	70
Mean	42.55	19.85
SD	8.46	4.70
CI95%	1.98	1.10
Lower	40.57	18.75
Upper	44.53	20.95

Key:

EOP: External occipital protuberance
MP: Mastoid process
GON: Greater occipital nerve
CI95%: Confidence interval of 95%
Lower: Lower range of values with a 95% confidence interval
Upper: Upper range of values with a 95% confidence interval

The average distance between the external occipital protuberance and the mastoid process was 42.55mm (range: 40.57mm – 44.53mm; all measurements with a 95% confidence interval), while the distance between the external occipital protuberance and the greater occipital nerve was measured at 19.85mm (range: 18.75mm – 20.95mm).

5.4.1.2 Simulation on infant cadavers

The bilateral measurements for Group 2 (6 infants, between 28 days and one year of age) are presented in Table 5.2.

Table 5.2: Infant cadavers of Group 2

	Distance EOP - MP	**Distance GON - EOP**
N	12	12
Mean	56.73	23.92
SD	17.42	6.03
CI95%	9.86	3.41
Lower	46.87	20.50
Upper	66.58	27.33

Key:

EOP: External occipital protuberance
MP: Mastoid process
GON: Greater occipital nerve
CI95%: Confidence interval of 95%
Lower: Lower range of values with a 95% confidence interval
Upper: Upper range of values with a 95% confidence interval

The measurements for the cadavers in Group 2 exhibited an average distance of 56.73mm (range: 46.87mm – 66.58mm) between the external occipital protuberance and the mastoid process, and 23.92mm (range: 20.50mm – 27.33mm) between the greater occipital nerve and the external occipital protuberance.

5.4.2 Relationship between the greater occipital nerve and the occipital artery

In two neonatal cadavers, the relationship between the greater occipital nerve and the occipital artery could not be described due to the occipital artery being removed during preliminary dissections. Therefore, the relationship between the two neurovascular structures was examined bilaterally in 33 specimens.

The relationship between the occipital artery and the greater occipital nerve, as they exit the trapezius muscle aponeurosis, was evaluated in 33 neonatal cadavers (Group 1) and six infant cadavers (Group 2) bilaterally, as seen in Table 5.3.

Table 5.3: Relationship between the greater occipital nerve and the occipital artery

	GROUP 1	GROUP 2
n	66	12
1	51	10
2	0	0
3	15	2

Key:

1: The occipital artery lies lateral to the greater occipital nerve
2: The occipital artery lies medial to the greater occipital nerve
3: The occipital artery lies between branches of the greater occipital nerve

In 77.3% (51/66) of the neonatal cadavers, the occipital artery was found lateral to the greater occipital nerve, while in 22.7% (15/66) of the cases, the artery was found between branches of the nerve. In the infant group, the occipital artery was found lateral to the greater occipital nerve in 83.3% (10/12), and between the branches of the greater occipital nerve in 16.7% (2/12) of the cadavers. In neither Group 1, nor Group 2, was the occipital artery found medial to the greater occipital nerve.

The distance between the greater occipital nerve and the occipital artery as they exit the trapezius muscle aponeurosis, is represented in Table 5.4.

Table 5.4: Distance between the greater occipital nerve and the occipital artery

	GROUP 1	GROUP 2
n	51	10
Mean	0.82	1.36
SD	0.44	0.79
CI95%	0.12	0.49
Lower	0.70	0.87
Upper	0.94	1.85

Key:

CI95%: Confidence interval of 95%
Lower: Lower range of values with a 95% confidence interval
Upper: Upper range of values with a 95% confidence interval

Table 5.4 represents the distances between the greater occipital nerve and the occipital artery in the cadavers where the artery was located lateral to the nerve. The occipital artery was located 0.82mm (range: 0.70mm – 0.94mm) lateral to the greater occipital nerve in Group 1, and 1.36mm (range: 0.87mm – 1.85mm) lateral to the nerve in Group 2, as both structures exit the trapezius muscle aponeurosis.

In the cases where the occipital artery passed between the branches of the greater occipital nerve as it passes through the trapezius aponeurosis, the distance between these neurovascular structures could not be determined. This occurred in 15 neonatal (Group 1) cadavers and two infant (Group 2) cadavers, as seen in Table 5.3.

5.4.3 Greater occipital nerve block in paediatric patients

In order to facilitate easier and more effective blocking of the greater occipital nerve in the paediatric population, a technique that allows for the blocking of the greater occipital nerve with greater ease, needs to be developed.

5.4.3.1 Determining the greater occipital nerve block in the neonatal population

In Table 5.5, the average measurements with regard to the fingers on the right hand of each of the neonates are displayed.

Table 5.5: Breadth of fingers on right hand for Group 1

	4 fingers	**3 fingers**	**2 fingers**	**1 finger**	**Thumb**
n	35	35	35	35	35
Mean	23.69	18.06	11.81	5.46	7.47
SD	6.30	4.85	3.29	1.61	3.80
CI95%	2.09	1.61	1.09	0.53	1.26
Lower	21.60	16.45	10.72	4.93	6.21
Upper	25.78	19.67	12.90	6.00	8.72

Key:

CI95%: Confidence interval of 95%
Lower: Lower range of values with a 95% confidence interval
Upper: Upper range of values with a 95% confidence interval

As seen in Table 5.5, the average measurement with regard to the fingers on the right hand of the neonatal cadavers was 23.69mm (range: 21.60mm – 25.78mm) for the medial four fingers. The medial three fingers exhibited a breadth of 18.06mm (range: 16.45mm – 19.67mm), while the medial two fingers measured 11.81mm (range: 10.72mm – 12.90mm). The little finger (medial finger) was 5.46mm (range: 4.93mm – 6.00mm) at the proximal interphalangeal joint and the thumb was 7.47mm (range: 6.21mm – 8.72mm) at the interphalangeal joint.

In order to correlate the breadth of the finger measurements to the distances obtained in aim 1, population correlation coefficients were determined to evaluate the relationship between the two set of distances.

Table 5.6 displays the values obtained after determining the Pearson correlation coefficients for the neonatal cadavers.

Table 5.6: Pearson correlation coefficient values for Group 1

	4 fingers	**3 fingers**	**2 fingers**	**1 finger**	**Thumb**
EOP – MP (R-value)	0.82	**0.83**	0.74	0.69	0.40
p-value	<.0001	<.0001	<.0001	<.0001	0.0182
GON – EOP (R-value)	**0.53**	0.51	0.44	0.29	0.31
p-value	0.0011	0.0016	0.0084	0.0945	0.0698

Key:

EOP: External occipital protuberance
MP: Mastoid process
GON: Greater occipital nerve

The distance between the external occipital protuberance and the mastoid process correlates positively with the values greater than 0.80 for the medial four and medial three fingers. This is considered statistically significant with a p-value smaller than 0.05. No positive correlations were observed between the fingers breadth and the distance between the greater occipital nerve and external occipital protuberance for Group 1.

5.4.3.2 Determining the greater occipital nerve block in the infant population

The breadths of the fingers on the right hand for the infant group are displayed in Table 5.7.

Table 5.7: Breadth of fingers on right hand for Group 2

	4 fingers	**3 fingers**	**2 fingers**	**1 finger**	**Thumb**
n	5	5	5	5	5
Mean	30.43	22.84	14.46	6.76	8.55
SD	7.78	6.41	4.50	1.74	2.41
CI95%	6.82	5.62	3.95	1.53	2.12
Lower	23.61	17.23	10.51	5.24	6.43
Upper	37.25	28.46	18.41	8.29	10.66

Key:

CI95%: Confidence interval of 95%
Lower: Lower range of values with a 95% confidence interval
Upper: Upper range of values with a 95% confidence interval

In Group 2, one infant cadaver's finger breadth could not be measured, since the arms were absent bilaterally. The average breadth of the fingers on the right hand, measured at the proximal interphalangeal joint, as seen in Table 5.7, was 30.43mm (range: 23.61mm – 37.25mm) for the medial four fingers; 22.84mm (range: 17.23mm – 28.46mm) for the medial three fingers; 14.46mm (range: 10.51mm – 18.41mm) for the medial two fingers and 6.76mm (range: 5.24mm – 8.29mm) for the little finger (medial finger). The average measurement for the interphalangeal joint breadth of the thumb was 8.55mm (range: 6.43mm – 10.66mm).

In Table 5.8, the Pearson correlation coefficients and p-values are presented.

Table 5.8: Pearson correlation coefficients for Group 2

	4 fingers	**3 fingers**	**2 fingers**	**1 finger**	**Thumb**
EOP – MP (R-value)	0.98	**0.99**	0.98	0.98	0.97
p-value	0.0016	0.0003	0.0019	0.0015	0.0072
GON – EOP (R-value)	0.96	**0.98**	0.95	0.97	0.93
p-value	0.0082	0.0054	0.0119	0.0051	0.023

Key:

EOP: External occipital protuberance
MP: Mastoid process
GON: Greater occipital nerve

The distances of both the external occipital protuberance to the mastoid process, and the external occipital protuberance to the greater occipital nerve, correlate positively with the measurements of all the finger breadths with coefficient values greater than 0.80. For the infant group, the breadth of the medial three fingers are the most compatible and statistically significant ($p < 0.05$) with the distance from the external occipital protuberance to the greater occipital nerve.

5.5 Discussion

The greater occipital nerve block is most commonly indicated in adults to alleviate pain associated with headache disorders such as occipital neuralgia (Dugan *et al.,* 1962; Ward, 2003' Loukas *et al.,* 2006; Natsis *et al.,* 2006; Levin, 2009; Tobin and Flitman, 2009; Eldrige *et al.,* 2010; VanderHoek *et al.,* 2013); cervicogenic headache (Bovim and Sand. 1992; Caputi and Firetto, 1997; Inan *et al.,* 2001; Naja *et al.,* 2006; Levin, 2009; Tobin and Flitman, 2009); migraines (Caputi and Firetto, 1997; Austad, 2004; Ashkenazi and Young, 2005; Dash *et al.,* 2005; Janis *et al.*, 2010a; Gelfand *et al.,* 2014) and cluster headaches (Peres *et al.,* 2002; Ambrosini *et al.,* 2005; Afridi *et al.,* 2006; Busch *et al.,* 2007; Tobin and Flitman, 2009; Lambru *et al.,* 2013).

In the paediatric population, a greater occipital nerve block can be administered during occipital craniotomies, as well as posterior shunt revisions (Suresh and Voronov, 2006; Henderson, 2009). Children who experience occipital neuralgia, can also undergo greater occipital nerve blocks to relieve experienced pain (Ward, 2003; Suresh and Voronov, 2006). Anaesthesia administered for the excision of skin lesions in the occipital region, as well as occipital incisions for the removal of posterior fossa tumours and the placements of ventriculo-peritoneal shunts, can also be achieved with a greater occipital nerve block (Suresh *et al.,* 2002; Suresh and Wagner, 2001).

Bala and co-workers (2006) cite that opioids such as morphine, tramadol and codeine can be used in postoperative pain control for neurosurgical patients, but they are linked to side effects. In order to avoid the side effects of systemic drugs, a regional technique, such as blocking the nerves supplying the scalp, is often a safer and better alternative for postoperative pain.

The greater occipital nerve is the medial branch of the second cervical posterior ramus. It travels deep to the semispinalis capitis muscle initially, after which it pierces the semispinalis capitis muscle. It then emerges onto the scalp by passing above an aponeurotic sling between the trapezius and sternocleidomastoid muscles (Standring, 2008).

In the adult population, one of the most common methods of blocking the greater occipital nerve is using a point on the medial one-third of the distance on the line between the external occipital protuberance and the mastoid process (Watson and Leslie, 2001; Costello and Cormack, 2004; Ashkenazi *et al.,* 2008; Levin, 2009; Ashkenazi *et al.,* 2010). Leroux and co-workers (2010), as well as Lambru and colleagues (2013), refer to the same point on the medial third of the line between the inion and the mastoid process. However, certain studies indicate that the greater occipital nerve can be located on the midpoint of the imaginary line between the external occipital protuberance and the mastoid process (Osborn and Sebeo, 2010) in relation to the superior nuchal line (Pinosky *et al.,* 1996; Busch *et al.,* 2005; Bala *et al.,* 2006).

Various locations for the greater occipital nerve have been reported, yet, no information on dissections of the greater occipital nerve in the paediatric population could be obtained. Suresh and Voronov (2012) state: “The midpoint of a line drawn between the mastoid process and the midline will be a good guide to the location of the greater occipital nerve.” However, this statement seems a bit vague, as the exact point on the midline is not described.

5.5.1 Measurements for the greater occipital nerve block

In order to determine an easy technique that can be executed with great accuracy, for blocking the greater occipital nerve in the paediatric population, clear descriptions of the nerve and its relations to various landmarks need to be described.

5.5.1.1 Simulation on neonatal cadavers

In Table 5.1 the results of the dissections relating to the greater occipital nerve and bony landmarks for the neonatal cadavers, are represented. The external occipital protuberance is on average 42.55mm (range: 40.57mm – 44.53mm) from the mastoid process, while the greater occipital nerve is 19.85mm (range: 18.75mm – 20.95mm) from the external occipital protuberance.

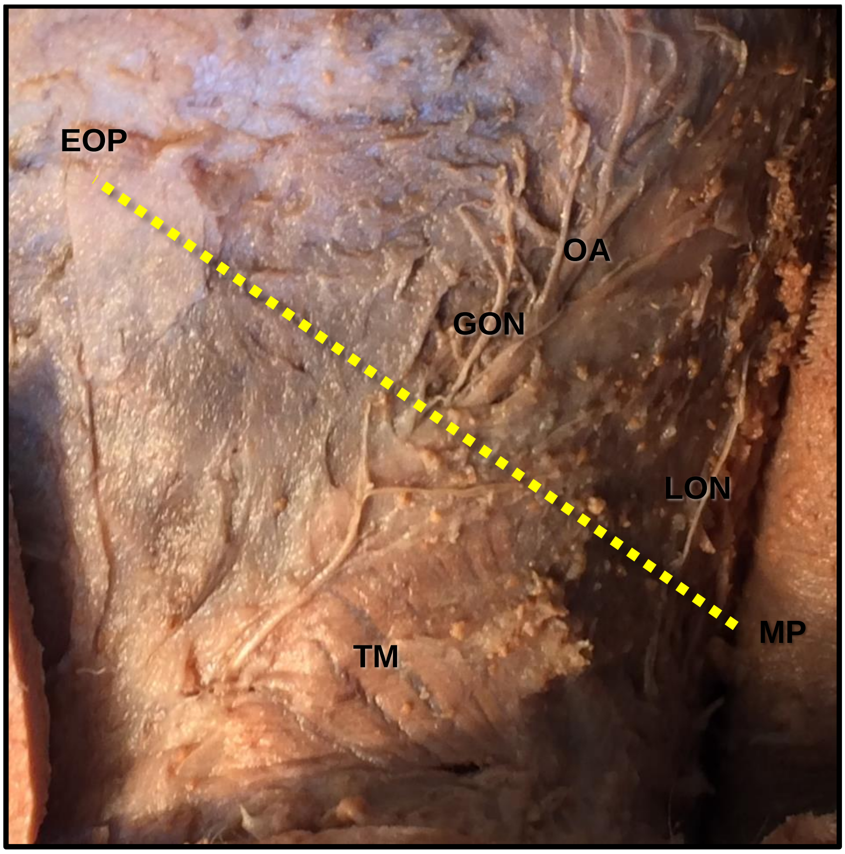


Figure 5.2: Greater occipital nerve and occipital artery exiting the right trapezius muscle aponeurosis in a neonatal cadaver. The yellow line indicates the line between the external occipital protuberance and mastoid process

[EOP – External occipital protuberance; GON – Greater occipital nerve; OA – Occipital artery; LON – Lesser occipital nerve; MP – Mastoid process; TM – Trapezius muscle]

The ratio between the distance from the external occipital protuberance and the greater occipital nerve, and the distance between the external occipital protuberance and mastoid process, can be expressed as a percentage. The distance between the external occipital protuberance and the greater occipital nerve is 46.65% of the distance between the external occipital protuberance and the mastoid process. Based on the results of this study, the greater occipital nerve exits the trapezius muscle aponeurosis approximately midway on the line between the external occipital protuberance and the mastoid process. This can be seen in Figure 5.2.

This finding compares well with the statement made by Suresh and Voronov (2012): “The midpoint of a line drawn between the mastoid process and the midline will be a good guide to the location of the greater occipital nerve.” It can now be confirmed that the direction of the line that they refer to, corresponds to the line between the external occipital protuberance and the mastoid process.

5.5.1.2 Simulation on infant cadavers

Six infant cadavers were dissected bilaterally in the occipital region to locate the greater occipital nerve and to determine its position relative to specific bony landmarks. The results can be seen in Table 5.2. With a 95% confidence interval, the external occipital protuberance is 56.73mm (range: 46.87mm – 66.58mm) from the mastoid process and 23.92mm (range: 20.50mm – 27.33mm) from the hiatus in the trapezius muscle aponeurosis where the greater occipital nerve emerges.

Figure 5.3 clearly indicates that the greater occipital nerve does not emerge at the midpoint of the line between the external occipital protuberance and mastoid process. The ratio between the distance from the external occipital protuberance to the greater occipital nerve, and the distance between the external occipital protuberance and mastoid process, is not a definite 50%.

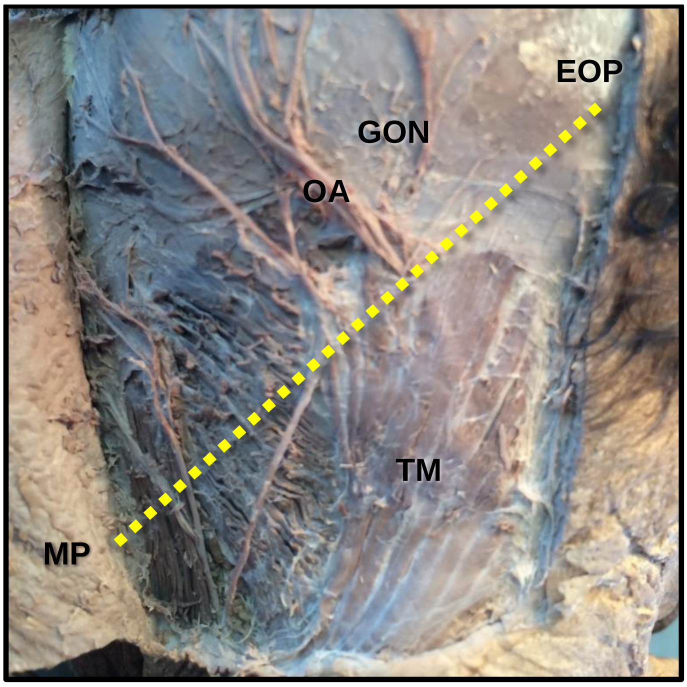


Figure 5.3: The greater occipital nerve emerges on the left occipital side of an infant cadaver, on the line between the external occipital protuberance and mastoid process

[EOP – External occipital protuberance; GON – Greater occipital nerve; OA – Occipital artery; TM – Trapezius muscle; MP – Mastoid process]

When comparing the distances between the landmarks, the distance of the external occipital protuberance to the greater occipital nerve is 42.6% of the distance between the external occipital protuberance and the mastoid process.

In adults, the point on the junction between the medial third and the lateral two-thirds on the line between the external occipital protuberance and mastoid process is often used to block the greater occipital nerve (Watson and Leslie, 2001; Costello and Cormack, 2004; Ashkenazi *et al.,* 2008; Levin, 2009; Ashkenazi *et al.,* 2010).

In order to apply the aforementioned statement to infants in the paediatric population, the distance between the greater occipital nerve and external occipital protuberance needed to be 18.91mm. For this point to correspond with the midpoint of the similar line in the neonatal population, the distance needed to be 28.37mm. In this study, the distance was measured at 23.92mm. Therefore, it can be argued that the distance decreases proportionately in relation to the distance between the external occipital protuberance and the mastoid process, as the individual ages.

When blocking the greater occipital nerve in paediatric patients, Seeger and colleagues (2015), used a point 20mm lateral and 20mm inferior to the external occipital protuberance for their injection site. In order to compare the results from this study with their results, mathematical reasoning is required. By applying the Pythagoras principle ($X^2 + Y^2 = Z^2$), their point will be located 28.28mm from the external occipital protuberance on the oblique line, as seen in Figure 5.4. Therefore, the two studies cannot be compared.

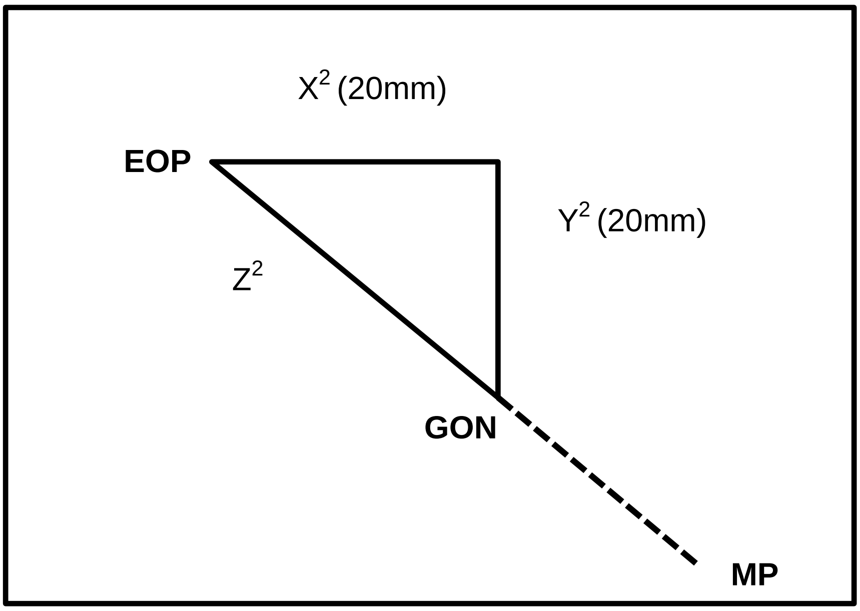


Figure 5.4: The principal of Pythagoras applied to the technique of Seeger *et al.* (2015)

[EOP – External occipital protuberance; GON – Greater occipital nerve; MP – Mastoid process]

5.5.2 Relationship between the greater occipital nerve and the occipital artery

The occipital artery is a posterior branch of the external carotid artery and arises approximately 20mm superior to the common carotid artery bifurcation. After being crossed superficially by the hypoglossal nerve, the artery ascends deep to the posterior belly of the digastric muscle. It crosses the internal carotid artery, internal jugular vein and hypoglossal, vagus and accessory nerves. It passes through the suboccipital triangle, in the occipital groove of the temporal bone and travels over the rectus capitis lateralis, superior oblique capitis and semispinalis capitis muscles. It is finally accompanied by the greater occipital nerve through the cranial attachment of the trapezius muscle and ascends in the subcutaneous occipital tissue (Standring, 2008).

In the paediatric population, the palpation of the occipital artery is used to locate and block the greater occipital nerve (Suresh and Wagner, 2001; Henderson, 2009; Suresh and Voronov, 2006; Suresh and Voronov, 2012; Szabova *et al.,* 2012). However, should intravascular injection occur due to the closely related occipital artery, complications could be encountered (Ward, 2003). The greater occipital nerve lies medial to the occipital artery (Polaner *et al.,* 2000; Suresh and Wagner, 2001; Ward, 2003; Henderson, 2009; Greher *et al.,* 2010; Osborn and Sebeo, 2010; VanderHoek *et al.,* 2013), though the artery is located medial to the nerve at the level of the superior nuchal line (Suresh and Voronov, 2012).

The relationship between the greater occipital nerve and the occipital artery in this paediatric sample is shown in Table 5.3. The results of this study indicate that the occipital artery lies lateral to the greater occipital nerve in 77.3% (51/66) of the neonatal specimens and 83.3% (10/12) of the infant group, which is consistent with the obtained literature (Polaner *et al.,* 2000; Suresh and Wagner, 2001; Ward, 2003; Henderson, 2009; Greher *et al.,* 2010; Osborn and Sebeo, 2010; VanderHoek *et al.,* 2013). This relationship can be seen in Figure 5.5.

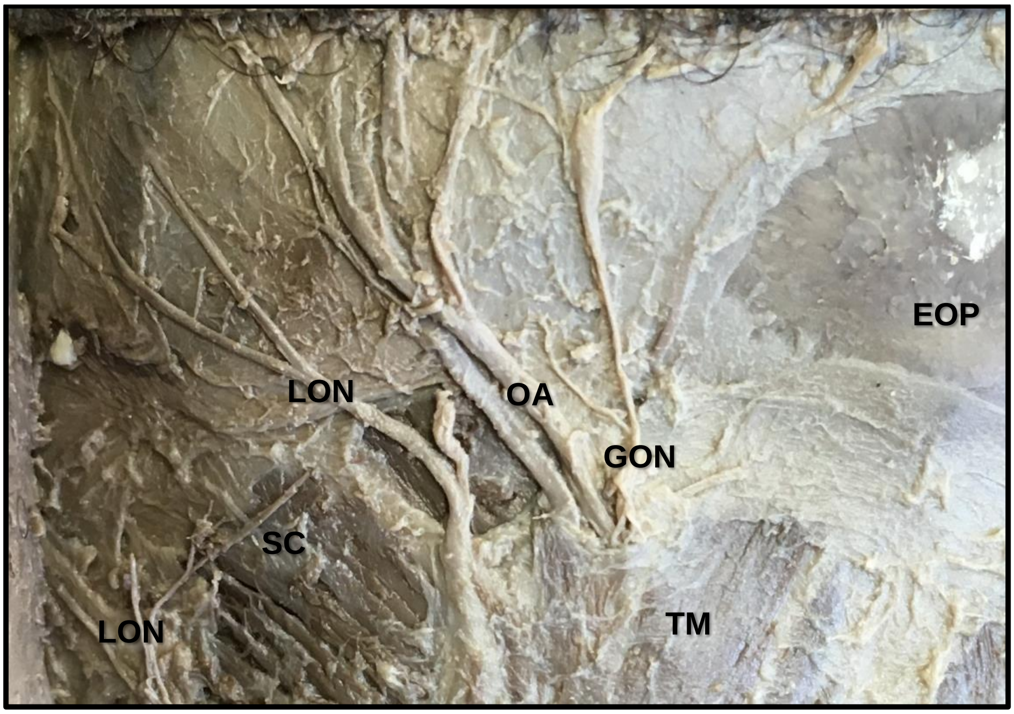


Figure 5.5: Occipital artery located lateral to the greater occipital nerve [LON – Lesser occipital nerve; SC – Splenius capitis muscle; OA – Occipital artery; GON – Greater occipital nerve; EOP – External occipital protuberance; TM – Trapezius muscle]

In Figure 5.5, the close relationship between the greater occipital nerve and the occipital artery can be seen as these structures pass through the hiatus in the trapezius muscle aponeurosis. This is in line with the statements by Ward (2003), Tubbs and co-workers (2007), Standring (2008) and Ducic *et al.* (2009) that the artery and the nerve travel together through the trapezius muscle.

In Group 1, however, 22.7% (15/66) of the specimens exhibited a different pattern, where the greater occipital nerve divided into its branches prior to exiting through the trapezius muscle aponeurosis. Therefore, the occipital artery was located between these branches and did not travel lateral to the nerve. This occurred in 16.7% (2/12) of the infant cadavers of Group 2. If the technique of palpation of the occipital artery is used when blocking the greater occipital nerve, this variation needs to be noted and can be seen in Figure 5.6.

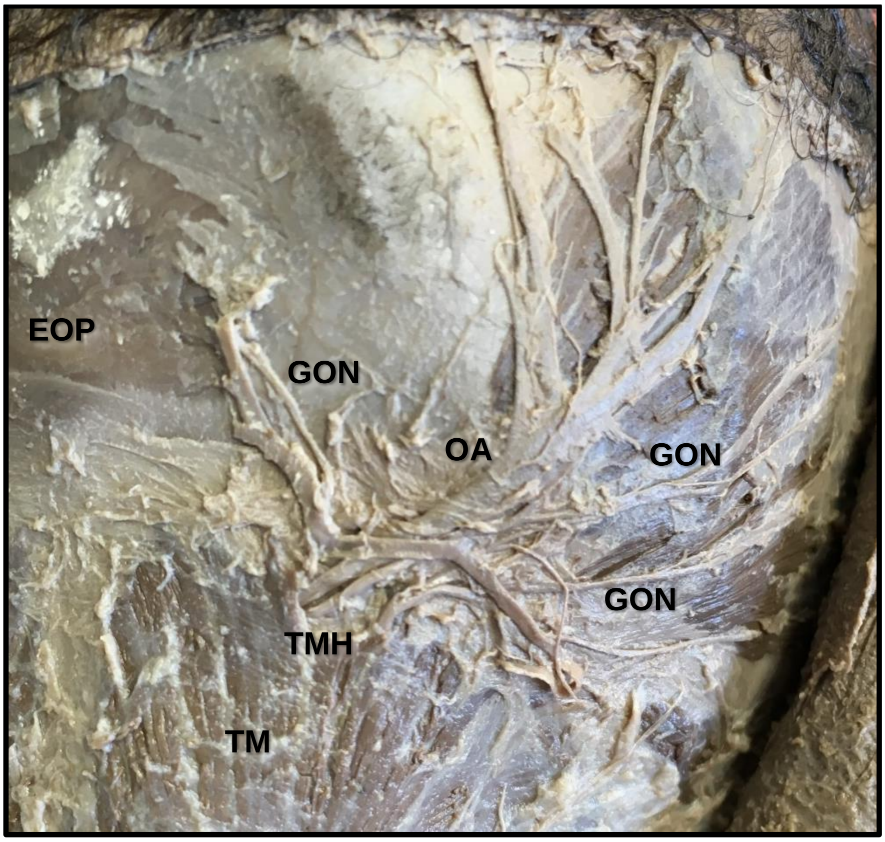


Figure 5.6: Occipital artery emerging from the trapezius muscle hiatus between branches of the greater occipital nerve

[EOP – External occipital protuberance; GON – Greater occipital nerve; OA – Occipital artery; TMH – Trapezius muscle hiatus; TM – Trapezius muscle]

Vital and co-workers (1989) concluded that in 26% of the specimens the greater occipital nerve divided into its terminal branches prior to travelling through the trapezius muscle aponeurosis. This corresponds well with the results from this study, which found that in 22.7% of the neonatal cadavers and 16.7% of the infant cadavers, the greater occipital nerve divides into its terminal branches. In this study, no supplementary openings were found containing branches of the greater occipital nerve.

In a study conducted by Natsis and colleagues (2006), they evaluated the course of the greater occipital nerve in the occipital area of 40 cadavers. In one aspect of their study, they observed the interactions between the greater occipital nerve and the occipital artery. They conclude that the greater occipital nerve and the occipital artery both pierce the trapezius muscle, yet this is done separately and well apart.

In Table 5.4 the average distance between the occipital artery and the greater occipital nerve is displayed. For Group 1, the average distance between the 51 sets of neurovascular structures is 0.82mm ± 0.12mm, while a distance of 1.36mm ± 0.49mm is observed for the 10 specimens of Group 2. These results exhibit a close relationship between the greater occipital nerve and the occipital artery, in contrast to the statement made by Natsis *et al.* (2006).

Janis and colleagues (2010a and b) published two separate articles on the relationship between the greater occipital nerve and the occipital artery, based on the assessment of 25 cadaveric heads. In the first article (2010a), the compression points of the greater occipital nerve were evaluated. They concluded that the occipital artery can intertwine, cross or compress the greater occipital nerve. In the second article, the occipital artery and the greater occipital nerve had a close relationship in 54% of the cases, either being a single interaction (29.6%) or a twisting and spiral relationship (70.4%).

Even though the exact relationship between these neurovascular structures were not evaluated in this study, the close connection and small distances between these structures are compatible to the results obtained by Janis and co-workers (2010a, b). Prevention of intravascular injection is of the utmost importance in order to avoid complications. Therefore, close association between the greater occipital nerve and the occipital artery requires special consideration when the greater occipital nerve is blocked in the paediatric population.

5.5.3 Greater occipital nerve block in paediatric patients

Becser and co-workers (1998) stated: “Detailed knowledge of the topography of these nerves is mandatory for optimizing these blocks.” This statement is referenced from the studies of Bovim *et al.* (1991) and Vital *et al.* (1989) and is used to accentuate the importance of anatomical knowledge on the nerves that supply the scalp.

No scientific articles on the anatomical dissections of the greater occipital nerve in the paediatric population could be obtained during a search of Google scholar or the scientific databases Ovid, Pubmed or Medline. Several authors (Suresh and Wagner, 2001: Suresh *et al.,* 2002; Ward, 2003; Suresh and Bellig, 2004; Suresh and Voronov, 2006; Henderson, 2009; Szabova *et al., 2012;* Gelfand *et al*., 2014; Seeger *et al*., 2015) refer to the use of the greater occipital nerve block on paediatric patients in their research articles, but the origin of the technique or the rationale behind the approach could not be ascertained.

Natsis and co-workers (2005) make the following valid statement: “Anesthetic success in the medium or long term is, however, uncertain without guidance on the optimum sites for administration of local anesthetic.” Through cadaveric studies, anatomical information on the distributions, relations and locations of these nerves are obtained, which will aid practicing clinicians in successfully performing regional nerve blocks on paediatric patients.

5.5.3.1 Determining the greater occipital nerve block in the neonatal population

The greater occipital nerve was dissected bilaterally and exposed in the occipital region of 35 neonatal cadavers. The greater occipital nerve exited the trapezius muscle aponeurosis and was accompanied by the occipital artery.

As seen in Table 5.1 the greater occipital nerve is located 19.85mm (range: 18.75mm – 20.95mm) from the external occipital protuberance. This is 46.65% of the distance between the external occipital protuberance and the mastoid process, approximately at the midpoint of the line between these two bony landmarks.

In order to create an easy method of locating the greater occipital nerve, the breadth of the fingers on the right hand of each cadaver was determined at the proximal interphalangeal joint and then compared to the distance between the greater occipital nerve and the external occipital protuberance. In Table 5.5, the breadths of the fingers are shown, and the closest comparison to the distance between the greater occipital nerve and the external occipital protuberance, is that of the medial three fingers. The average breadth of the medial three fingers was calculated at 18.06mm (range: 16:45mm – 19.67mm).

To accurately state that the distance between the greater occipital nerve and the external occipital protuberance correlates to the breadth of the same cadaver's medial three fingers, a population correlation coefficient was determined. The Pearson correlation coefficient values for Group 1 are seen in Table 5.6.

For this research study, a positive correlation greater than 0.80 was required to state that the distance between the greater occipital nerve and the external occipital protuberance correlates well with the breadth of the medial three fingers. However, in Table 5.6 it can be seen than the Pearson's correlation coefficient for the medial three fingers to the distance was determined at 0.51 with a p-value of 0.0016. Even though this correlation coefficient is statistically significant (p-value < 0.05), the value is not greater than 0.80.

To summarize the anatomical information obtained with regard to the greater occipital nerve in a neonatal population (Group 1): The greater occipital nerve is found approximately half-way between the external occipital protuberance and the mastoid process. This distance corresponds with the average breadth of the medial three fingers at the proximal interphalangeal joint. The occipital artery lies lateral to the greater occipital nerve in 77.3% of the cases. In order to minimise possible complications by means of intravascular injection of the anaesthetic fluid, aspiration should be performed, as recommended by Suresh and Wheeler (2002), Natsis *et al,* (2005), Suresh and Voronov (2006), and Suresh and Voronov (2012).

The following technique for blocking the greater occipital nerve is proposed: In the neonatal population, the greater occipital nerve is found midway between the external occipital protuberance and the mastoid process, medial to the occipital artery.

5.5.3.2 Determining the greater occipital nerve block in the infant population

Six infant (Group 2) cadavers were dissected bilaterally in the occipital region to expose the greater occipital nerve and the accompanying occipital artery. These neurovascular structures travel between the semispinalis capitis and trapezius muscles, traversing the latter as they become subcutaneous (Ward, 2003; Ducic *et al.,* 2009; Suresh and Voronov, 2009).

In Table 5.2 the distance between the external occipital protuberance and the greater occipital nerve is determined as 23.92mm (range: 20.50mm – 27.33mm), which relates to 42.6% of the distance between the external occipital protuberance and the mastoid process, which was measured at 56.73mm (range: 46.87mm – 66.58mm).

To facilitate in the blocking of the greater occipital nerve in the infant population, the proximal interphalangeal breadth of the right hand of each cadaver is displayed in Table 5.7. The three medial fingers measured a collective breadth of 22.84mm (range: 17.23mm – 28.46mm) at the proximal interphalangeal joint, which can closely be compared to the distance between the greater occipital nerve and the external occipital protuberance.

The Pearson population correlation coefficient was determined between the measurements on the breadth of the fingers and the distances between the greater occipital nerve and specific bony landmarks, as seen in Table 5.8. The highest correlation coefficient between the two measured variables was 0.99. This indicates that a very strong positive correlation exists between the breadth of the medial three fingers and the distance between the greater occipital nerve and the external occipital protuberance for each individual cadaver. This correlation coefficient is statistically very significant with a p-value of 0.0003, thus less than 0.05.

The following anatomical descriptions were obtained during the dissections of the occipital area in infants (Group 2): The greater occipital nerve is found 23.92mm from the external occipital protuberance. This distance corresponds with the proximal interphalangeal breadth of the medial three fingers of the cadaver. The greater occipital nerve lies medial to the occipital artery in 83.3% of the cases.

The following technique for blocking the greater occipital nerve in infants is proposed: The greater occipital nerve is located 24mm (medial three fingers' breadth) from the external occipital protuberance, on the line between the external occipital protuberance and the mastoid process, medial to the occipital artery.

5.6 Limitations of this study and proposed future research

The following limitations on this part of the research study were been identified and are proposed for future research studies:

1. Deeper dissections are required in a paediatric population to evaluate the relationship between the greater occipital nerve and the underlying muscles, especially semispinalis capitis. This is important to ascertain a possible secondary location for blocking the greater occipital nerve prior to the origin of its branches.

2. Supplementary observations of the communications between the greater occipital nerve and the lesser and third occipital nerves are required in the paediatric population. This information will facilitate clinicians during the diagnosis and treatment of pain disorders.

3. The exact branching pattern of the greater occipital nerve with regard to the levels of branching and the distribution of each branch is required in the paediatric population. This will ensure that the best possible location for blocking the greater occipital nerve is established, before any branches arise from the nerve.

4. The precise relationship between the greater occipital nerve and the occipital artery with regard to a single or multiple interconnections in the paediatric population is required to ensure that adequate knowledge is obtained to prevent possible complications such as intravascular injections.

5. The small infant sample can be seen as a limitation of this study. This can be attributed to the scarcity of available donated specimens. However, the infant and neonatal data are still invaluable and will greatly assist clinicians performing this nerve block in the paediatric population.

5.7 Conclusion

The greater occipital nerve block is predominantly used in the paediatric population for postoperative pain control in the case of craniotomies and shunt revisions (Suresh and Voronov, 2006; Henderson, 2009), as well as for pain relief in occipital neuralgia (Ward, 2003; Suresh and Voronov, 2006). The greater occipital nerve can be blocked medial to the occipital artery, midway between the external occipital protuberance and the mastoid process in neonates, and at a point equal to the three medial fingers breadth lateral to the external occipital protuberance, on the same line, in infants.

This study hopes to assist practising anaesthesiologists and clinicians to safely and accurately administer a greater occipital nerve block in the paediatric population, based on measurements and analyses of paediatric anatomical specimens.

5.8 References

Afridi, SK; Shield, KG; Bhola, R; Goadsby, PJ. (2006) Greater occipital nerve injection in primary headache syndromes – prolonged effects from a single injection. Pain 122: 126 – 129

Ambrosini, A; Vandenheede, M; Rossi, P; Aloj, F; Sauli, E; Pierelli, F; Schoenen, J. (2005) Suboccipital injection with a mixture of rapid- and long-acting steroids in cluster headache: A double-blind placebo-controlled study. Pain 118: 92 – 96

Anthony, M. (2000) Cervicogenic headache: prevalence and response to local steroid therapy. Clin Exp Rheumatol 18(Suppl 19): 59 – 64

Arruda, MA; Bigal, ME. (2012) Migraine and migraine subtypes in preadolescent children association with school performance. *Neurol* 79: 1881 – 1888

Ashkenazi, A; Young, WB. (2005) The effects of greater occipital nerve block and trigger point injection on brush allodynia and pain in migraine. *Headache* 45: 350 – 354

Ashkenazi, A; Matro, R; Shaw, JW; Abbas, MA; Silberstein, SD. (2008) Greater occipital nerve block using local anaesthetics alone or with triamcinolone for transformed migraine: a randomised comparative study. *J Neurol Neurosurg Psychiatry* 79: 415 – 417

Ashkenanzi, A; Blumenfield, A; Napchan, U; Narouze, S; Grosberg, B; Nett, R; DePalma, T; Rosenthal, B; Tepper, S; Lipton, RB. (2010) Peripheral nerve blocks and trigger point injections in headache management – a systematic review and suggestions for future research (Review article). *Headache* 50: 943 – 952

Austad, ED. (2004) The anatomy of the greater occipital nerve: implications for the etiology of migraine headaches (Discussion). *Plast Reconstr Surg* 113(2): 698 – 700

Bala, I; Gupta, B; Bhardwaj, N; Ghai, B; Khosla, VK. (2006) Effect of scalp block on postoperative pain relief in craniotomy patients. *Anaesth Intensive Care* 34(2): 224 – 227

Becser, N; Bovim, G; Sjaastad, O. (1998) Extracranial nerves in the posterior part of the head. Anatomic variations and their possible clinical significance. *Spine* 23: 1435 – 1441

Bogduk, N. (1982) The clinical anatomy of the cervical dorsal rami. *Spine* 7: 319 – 330

Bovim, G; Bonamico, L; Fredriksen, TA. Lindboe, CF; Stolt-Nielsen, A; Sjaastad, O. (1991) Topographic variations in the peripheral course of the greater occipital nerve. Autopsy study with clinical correlations. *Spine* 16: 475 – 478

Bovim, G; Sand, T. (1992) Cervicogenic headache, migraine without aura and tension-type headache. Diagnostic blockade of greater occipital and supra-orbital nerves. *Pain* 51: 43 – 48

Busch, V; Jakob, W; Juergens, T; Schulte-Mattler, W; Kaube, H; May, A. (2005) Functional connectivity between trigeminal and occipital nerves revealed by occipital nerve blockade and nociceptive blink reflexes. *Cephalalgia* 26: 50 – 55

Busch, V; Jakob, W; Juergens, T; Schulte-Mattler, W; Kaube, H; May, A. (2007) Occipital nerve blockade in chronic cluster headache patients and functional connectivity between trigeminal and occipital nerves. *Cephalalgia* 27: 1206 – 1214

Caputi, CA; Firetto, V. (1997) Therapeutic blockade of greater occipital and supraorbital nerves in migraine patients. *Headache* 37: 174 – 179

Choi, HJ; Choi, SK; Lee, SH; Lim, YJ. (2012) Whiplash injury-induced atypical short-lasting unilateral neuralgiform headache with conjunctival injection and tearing syndrome treated by greater occipital nerve block. *Clin J Pain* 28(4): 342 – 343

Costello, TG; Cormack, JR. (2004) Anaesthesia for awake craniotomy: a modern approach. *J Clin Neurosci* 11(1): 16 – 19

Dash, KS; Janis, JE; Guyuron, B. (2005) The lesser and third occipital nerves and migraine headaches. *Plast Reconstr Surg* 115: 1752 – 1758

Ducic, I; Moriarty, M; Al-Attar, A. (2009) Anatomical variations of the occipital nerves: implications for the treatment of chronic headaches. *Plast Reconst Surg* 123(3): 859 – 863

Dugan, MC; Locke, S; Gallagher, JR. (1962) Occipital neuralgia in adolescents and young adults. *N Engl J Med* 267: 1166 – 1172

Eldrige, JS; Obray, JB; Pingree, MJ; Hoelzer, BC. (2010) Occipital neuromodulation: ultrasound guidance for peripheral nerve stimulator implantation. *Pain Pract* 10(6): 580 – 585

Gawel, MJ; Rothbart, PJ. (1992) Occipital nerve block in the management of headache and cervical pain. *Cephalalgia* 12: 9 – 13

Gelfand, AA; Reider, AC; Goadsby, PJ. (2014) Outcomes of greater occipital nerve injections in pediatric patients with chronic primary headache disorders. *Pediatr Neurol* 50: 135 – 139

Gille, O; Lavignolle, B; Vital, JM. (2004) Surgical treatment of greater occipital neuralgia by neurolysis of the greater occipital nerve and sectioning of the inferior oblique muscle. *Spine* 29(7): 828 – 832

Greher, M; Moriggl, B; Curatolo, M; Kirchmair, L; Eichenberger, U. (2010) Sonographic visualization and ultrasound-guided blockade of the greater occipital nerve: a comparison of two selective techniques confirmed by anatomical dissection. *Br J Anaesth* 104: 637 – 642

Hartley, EJ; Bissonnette, B; St-Louis, P; Rybczynski, J; McLeod, ME. (1991) Scalp infiltration with Bupivacaine in pediatric brain surgery. *Anesth Analg* 73: 29 – 32

Henderson, K. (2009) Peripheral nerve blocks: a color atlas. 3rd edition. Editor: JE Chelly; Chapter 55: Peripheral nerve blockade of the head and neck. p 364 – 368

Herlich, A. (2012) Focused local anesthesia and analgesia for head and neck surgery. *International anesthesiology clinics* 50(1): 13 – 25

Inan, N; Ceyhan, A; Inan, L; Kavaklioglu, O; Alptekin, A; Unal, N. (2001) C2/C3 nerve blocks and greater occipital nerve block in cervicogenic headache treatment. *Funct Neurol* 16: 239 – 243

Janis, JE; Hatef, DA; Ducic, I; Reece, EM; Hamawy, AH; Becker, S; Guyuron, B. (2010a) The anatomy of the greater occipital nerve: Part II. Compression point topography. *Plast Reconstr Surg* 126: 1563 – 1572

Janis, JE; Hatef, DA; Reece, EM; McCluskey, PD; Schaub, TA; Guyuron, B. (2010b) Neurovascular compression of the greater occipital nerve: Implications for migraine headaches. *Plast Reconstr Surg* 126: 1996 – 2001

Lambru, G; Abu Bakar, N; Stahlhut, L; McCulloch, S; Miller, S; Shanahan, P; Matharu, MS. (2013) Greater occipital nerve blocks in chronic cluster headache: a prospective open-label study. *Eur J Neurol* 21: 338 – 343

Lavin, PJ; Workman. R. (2001) Cushing syndrome induced by serial occipital nerve blocks containing corticosteroids. *Headache* 41: 902 – 904

Leroux, E; Valade, D; Taifas, I; Vicaut, E; Chagnon, M; Roos, C; Ducros, A. (2011) Suboccipital steroid injections for transitional treatment of patients with more than two cluster headache attacks per day: a randomised, double-blind, placebo-controlled trail. *The Lancet Neurol* 10: 891 – 897

Levin, M. (2009) Nerve blocks and nerve stimulation in headache disorders. *Tech Reg Anaesth Pain Manag* 13: 42 – 49

Lipton, RB; Manack, A; Ricci, JA: Chee, E; Turkel, CC; Winner, P. (2011) Prevalence and burden of chronic migraine in adolescents: results of the chronic daily headache in adolescents study (C-dAS). *Headache* 51(5): 696 – 706

Loukas, M; El-Sedfy, A; Tubbs, RS; Louis Jr, RG; Wartmann, Ch T, Curry, B; Jordan, R. (2006) Identification of greater occipital nerve landmarks for the treatment of occipital neuralgia. *Folia Morphol* 65(4): 337 – 342

McDonald, JH. (2014) Handbook of Biological Statistics (3rd ed.). Sparky House Publishing, Baltimore, Maryland. p 126 – 130

MedCalc. (2016) Complete statistical program for windows. Information obtained 18-7-2016 from https://www.medcalc.org/manual/intraclasscorrelation.php

Mosser, SW; Guyuron, B; Janis, JE; Rohrich, RJ. (2004) The anatomy of the greater occipital nerve: implications for the etiology of migraine headaches. *Plast Reconstr Surg* 113: 693 – 697

Naja, ZM; El-Rajab, M; Al-Tannir, MA; Ziade, FM; Tawfik, OM. (2006) Occipital nerve blockade for cervicogenic headache: A double-blind randomized controlled clinical trail. *Pain Pract* 6(2): 89 – 95

Natsis, K; Baraliakos, X; Appell, HJ: Tsikaras, P; Gigis, I; Koebke, J. (2006) The course of the greater occipital nerve in the suboccipital region: a proposal for setting landmarks for local anesthesia in patients with occipital neuralgia. *Clin Anat* 19: 332 – 336

Nguyen, A; Girard, F; Boudreault, D; Fugere, F; Ruel, M; Moumdjian, R; Bouthilier, A; Caron, JC; Bojanowski, MW; Girard, DC. (2001) Scalp nerve blocks decrease the severity of pain after craniotomy. *Anesth Analg* 93 (5): 1272 – 1276

Okuda, Y; Matsumoto, T; Shinohara, M; Kitajima, T; Kim, P. (2001) Sudden unconsciousness during a lesser occipital nerve block in a patient with the occipital bone defect. *Eur J Anaesthesiol* 18: 829 – 832

Osborn, I; Sebeo, J. (2010) “Scalp block” during craniotomy: a classic technique revisited (Review article). *Neurosurg Anesthesiol* 22(3): 187 – 194

Peres, MFP; Stiles, MA; Siow, HC; Rozen, TD; Young, WB; Silberstein, SD. (2002) Greater occipital nerve blockade for cluster headache. *Cephalalgia* 22: 520 – 522

Pinosky, ML: Fishman, RL; Reeves, ST; Harvey, SC; Patel, S; Palesch, Y; Dorman, BH. (1996) The effect of bupivacaine skull block on the hemodynamic response to craniotomy. *Anest Analg* 83: 1256 – 1261

Polaner, D; Suresh S, Cote, CJ. (2000) Pediatric regional anesthesia. A Practice of anesthesia for infants and children. Cotes, C; Todres, ID; Ryan, JF; Goudsouzian, NG eds. Philadelphia, PA: WB Saunders Co., p 636 – 675

Seeger, TA; Orr, S; Bodell, L; Lockyer, L; Rajapakse, T; Barlow, KM. (2015) Occipital nerve blocks for pediatric posttraumatic headache: a case series. *J Child Neurol* 30(9): 1142 – 1146

Sprenger, T; Seifert, CL. (2013) Coma after greater occipital nerve blockade in a patient with previous posterior fossa surgery. *Headache* 53: 548 – 550

Standring, S. (2008) Gray's anatomy. 40th edition. The anatomical basis of clinical practice. Churchill, Livingstone, Elsevier. Chapter 43, p 447, 755

Suresh, S; Barcelona, S; Young, N; Selligman, I; Heffner, CL; Cote, CJ (2002) Postoperative pain relief in children undergoing tympanomastoid surgery: Is a regional block better than opioids? *Anest Analg* 94: 859 – 862

Suresh, S; Bellig, G. (2004) Regional anesthesia in a very low-birth-weight neonate for a neurosurgical procedure. *Reg Anesth Pain Med* 29: 58 – 59

Suresh, S; Voronov, P. (2006) Review article. Head and neck blocks in children: an anatomical and procedural review. *Ped Anesth* 16: 910 – 918

Suresh, S; Voronov, P. (2012) Review article. Head and neck blocks in infants, children, and adolescents. *Ped Anesth* 22: 81 – 87

Suresh, S; Wagner, AM. (2001) Scalp excisions: getting "ahead" of pain. *Pediatr Dermatol* 18(1): 74 – 76

Suresh, S; Wheeler, M. (2002) Practical pediatric regional anesthesia. New concepts and techniques in pediatric anesthesia: Volume 20, Number 1, (March) of Anesthesiology Clinics of North America. Linda J Mason and Michelle S Kim, editors Darien, Illinois: WB Saunders Company. p 83 - 113

Szabova, A; Goldschneider, K; Rose, J. (2012) Special considerations and recommendations for interventions for Pediatric chronic pain. *International anesthesiology clinics* 50(4): 120 – 129

Tank, PW. (2013) E-book: Grant's dissector. 15th edition . Lippincott Williams and Wilkins. Chapter 1, p 15

Tobin, J; Flitman, S. (2009) Occipital nerve blocks: When and what to inject? (Review article) *Headache* 49: 1521 – 1533

Tubbs, RS; Salter, EG; Wellons, JC; Blount, JP; Oakes, WJ. (2007) Landmarks for the identification of the cutaneous nerves of the occiput and nuchal regions. *Clin Anat* 20: 235 – 238

VanderHoek, MD; Hoang, HT; Goff, B. (2013) Ultrasound-guided greater occipital nerve blocks and pulsed radiofrequence ablation for diagnosis and treatment of occipital neuralgia. *Anesth Pain* 3: 256 – 259

Vanelderen, P; Rouwette, T; De Vooght, P; Puylaert, M; Heylen, R; Vissers, K; Van Zundert, J. (2010) Pulsed radiofrequency for the treatment of occipital neuralgia. A propspective study with 6 months of follow-up. *Reg Anesth Pain Manag* 35(2): 148 – 151

Vital, JM; Grenier, F; Dautheribes, M; Baspeyre, H; Lavignolle, B; Sénégas, J. (1989) An anatomic and dynamic study of the greater occipital nerve (n. of Arnold). *Surg Radiol Anat* 11: 205 – 210

Ward, JB. (2003) Greater occipital nerve block. *Semin Neurol* 23: 59 – 62

Watson, R; Leslie, K. (2001) Nerve blocks versus subcutaneous infiltration for stereotactic frame placement. *Anest Analg* 92: 424 – 427

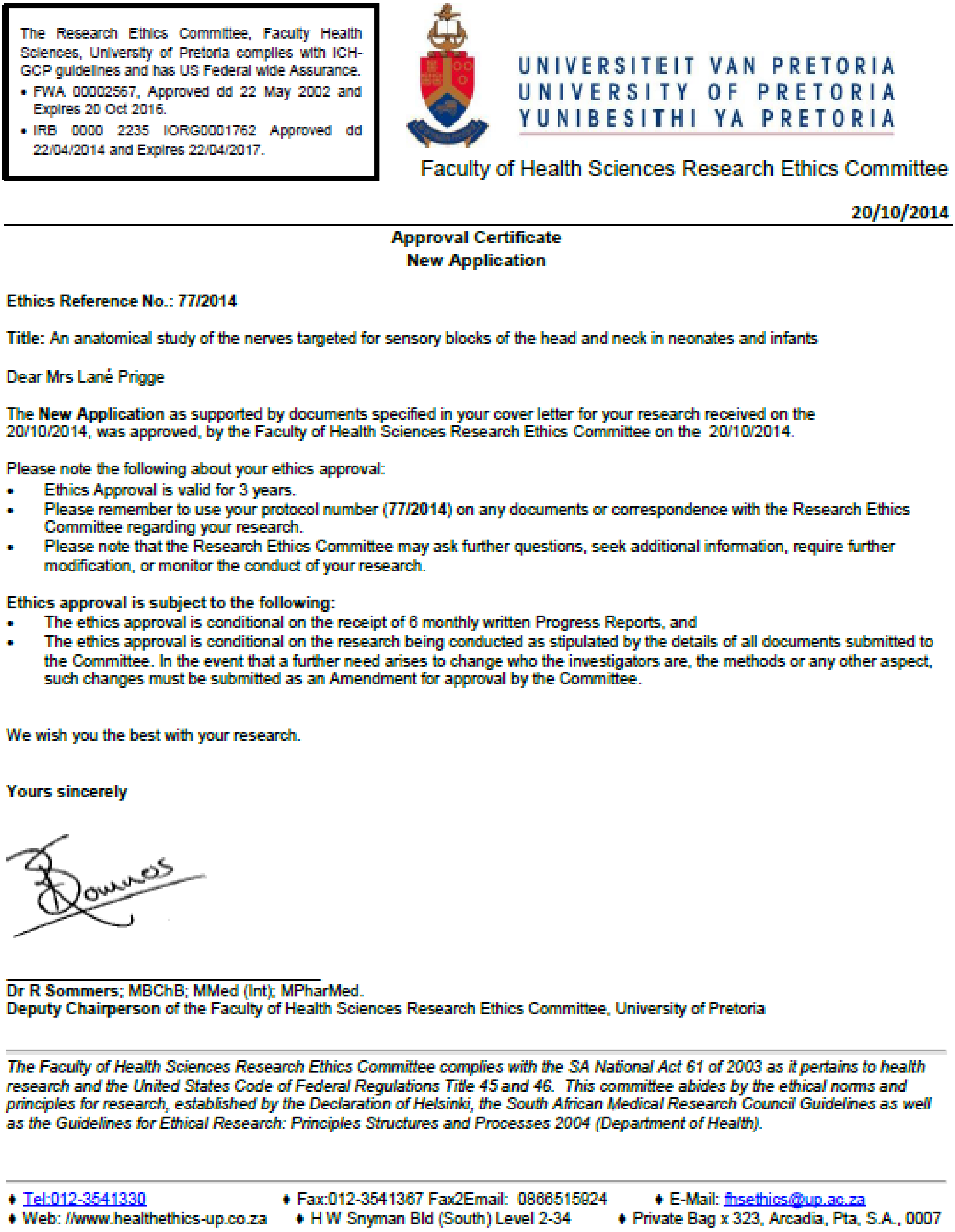
6 Conclusion

In the paediatric population, neonates and infants often require surgical intervention that is frequently accompanied by extreme postoperative pain. In order to minimise the administration of opioids and thereby possible opioid related complications, regional anaesthetic nerve blocks can be performed. These regional nerve blocks can also assist in minimising postoperative pain. However, very little paediatric applicable anatomy research and textbooks are available, resulting in adult standards often being extrapolated or disproportionately modified in order to achieve analgesia in paediatric patients.

Paediatric anatomical research studies, such as this one, are considered vital to any anaesthesiologist or clinician performing paediatric regional nerve blocks. Even though the anatomy related to paediatric patients does not differ greatly from their adult counterparts, the relationships and positions encountered, do. By means of quantitative data obtained through measurements and observations between peripheral nerves and associated soft and / or bony landmarks, easily performed techniques for these head and neck nerve blocks in the paediatric population are proposed.

In conclusion, this anatomical study on the nerves targeted for sensory blocks of the head and neck region in neonates and infants, will result in the substantial improvement of the relevant anatomical knowledge required. Subsequently, fewer difficulties and complications will be encountered, which will ensure that these paediatric nerve blocks are executed with greater confidence and ease by the performing clinicians.

Appendix A



The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.
- FWA 00002567, Approved dd 22 May 2002 and Expires 20 Oct 2016.
- IRB 0000 2235 IORG0001762 Approved dd 22/04/2014 and Expires 22/04/2017.

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Health Sciences Research Ethics Committee

20/10/2014

Approval Certificate
New Application

Ethics Reference No.: 77/2014

Title: An anatomical study of the nerves targeted for sensory blocks of the head and neck in neonates and infants

Dear Mrs Lané Prigge

The **New Application** as supported by documents specified in your cover letter for your research received on the 20/10/2014, was approved, by the Faculty of Health Sciences Research Ethics Committee on the 20/10/2014.

Please note the following about your ethics approval:
- Ethics Approval is valid for 3 years.
- Please remember to use your protocol number (**77/2014**) on any documents or correspondence with the Research Ethics Committee regarding your research.
- Please note that the Research Ethics Committee may ask further questions, seek additional information, require further modification, or monitor the conduct of your research.

Ethics approval is subject to the following:
- The ethics approval is conditional on the receipt of 6 monthly written Progress Reports, and
- The ethics approval is conditional on the research being conducted as stipulated by the details of all documents submitted to the Committee. In the event that a further need arises to change who the investigators are, the methods or any other aspect, such changes must be submitted as an Amendment for approval by the Committee.

We wish you the best with your research.

Yours sincerely

Dr R Sommers; MBChB; MMed (Int); MPharMed.
Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

The Faculty of Health Sciences Research Ethics Committee complies with the SA National Act 61 of 2003 as it pertains to health research and the United States Code of Federal Regulations Title 45 and 46. This committee abides by the ethical norms and principles for research, established by the Declaration of Helsinki, the South African Medical Research Council Guidelines as well as the Guidelines for Ethical Research: Principles Structures and Processes 2004 (Department of Health).

♦ Tel:012-3541330 ♦ Fax:012-3541367 Fax2Email: 0866515924 ♦ E-Mail: fhsethics@up.ac.za
♦ Web: //www.healthethics-up.co.za ♦ H W Snyman Bld (South) Level 2-34 ♦ Private Bag x 323, Arcadia, Pta, S.A., 0007

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Faculty of Health Sciences Research Ethics Committee

5/04/2018

Mrs Lane Prigge
Department of Anatomy
University of Pretoria

Dear Mrs Lane Prigge

RE.: 77/2014 ~ Letter dated 27 February 2018

PROTOCOL NUMBER	**77/2014**
RIMS	Not on RIMS – paper version only
PRINCIPAL INVESTIGATOR	Mrs Lané Prigge **Dept:** Anatomy Department/ Hospital/ Institution: University of Pretoria. Cell: 0823817256 E-Mail: lane.prigge@ul.ac.za
TITLE OF RESEARCH PROJECT	An anatomical study of the nerves targeted for sensory blocks of the head and neck in neonates and infants

We hereby acknowledge receipt of the following document:

- Extension of study until the end of November 2018

which has been approved at 28 March 2018 meeting.

With regards

Dr R Sommers; MBChB; MMed (Int); MPharMed; PhD
Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

☎ 012 356 3085 fhsethics.up.ac.za http://www.up.ac.za/healthethics
✉ Private Bag X323, Arcadia, 0007 - Tswelopele Building, Level 4-59, Gezina, Pretoria