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Maastricht University

Faculty of Medicine and Life Sciences
School for Life Sciences
Master of Biomedical Sciences

Master's thesis

An upper arm Bier block versus a forearm mini-Bier block: a randomized controlled trial in patients undergoing hand surgery

Victoria Broux

Thesis presented in fulfillment of the requirements for the degree of Master of Biomedical Sciences, specialization Clinical Molecular Sciences

SUPERVISOR :
Prof. dr. Björn STESSEL

MENTOR :
dr. Ina CALLEBAUT

2018
2019

Transnational University Limburg is a unique collaboration of two universities in two countries: the University of Hasselt and Maastricht University.

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ACKNOWLEDGEMENTS

Hasselt University and the Jessa hospital gave me the opportunity to perform my senior practical internship at the department of Anaesthesiology. Their confidence and assistance are highly appreciated. Throughout the past seven months I met a lot of helpful, motivated and supportive people who helped me perform this study.

At first, I would like to thank my supervisor Dr. Björn Stessel for giving me the chance to carry out this study and to bring the theory that I learned during my education in to practice. Thank you also for giving me wise advice and answers and for being so optimistic and encouraging every time we met. Furthermore, I would like to thank my daily supervisor dr. Ina Callebaut for guiding me throughout the past several months and for always being there for me whether it was for a quick answer (even at 10 pm) or for a long review of my thesis, for taking over some of the patient inclusions whenever I was not available, and for giving me more confidence in myself.

A kind thank you goes out to all the post-docs, PhD students, Sandra and Hilde, from "House 81", who gave me knowledge and support as experienced professionals in the clinical science setting. A special thank you to Bénedith, who was always concerned about me and encouraged me to finish my thesis in time and for always creating a free moment in case I was in need for a motivating chat.

Together with Lene, Sofie, Lore and Lieselotte, I started my senior internship, each at our own department, but together "at the office". Thanks to each and every one of you for becoming such good friends as we are at this point. We literally laughed, cried, listened, celebrated, supported, worked as a team, motivated, assisted, cheered each other up, and shared qualities and talents. It made each day go 10 times as fast and made me happily come back every day. Good luck to you all in your future lives and further scientific careers.

I would also like to show my appreciation to the head of the Anaesthesiology department: Dr. Ory, the anaesthesiologists, assistant-anaesthesiologists, and surgeons who made it possible to perform this study and for getting me started in the operation room. Thank you also to the nurses of day care who guided me with including patients for the study.

Furthermore, I would like to thank my best friends (Astrid, Angie, Leen, and Karen) who I met at the first day of Uni. Without you guys none of the past 5 years would have been as fun and joyful as they were with you all. I wish you all the best of luck.

Last but not least I would like to thank my parents, my sisters Jennifer and Jacqueline, and my boyfriend Brecht for always believing in me and my capabilities, for supporting and motivating me, and for helping me become a scientist.

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LIST OF ABBREVIATIONS

Abductor pollicis longus	APL
American Society of Anaesthesiologists	ASA
American Society of Anaesthesiologists physical status	ASAPS
Body Mass Index	BMI
Carpal tunnel syndrome	CTS
Central nervous system	CNS
Consolidated Standards of Reporting Trials	CONSORT
Dissociation Constant	pKa
Extensor pollicis brevis	EPB
General anaesthesia	GA
Informed Consent	IC
Interquartile range	IQR
Intravenous regional anaesthesia	IVRA
Intravenous	IV
Local anaesthetic systemic toxicity	LAST
Local anaesthetic	LA
Numerical rating scale	NRS
Operating room	OR
Regional anaesthesia	RA

ABSTRACT

Background: Intravenous regional anaesthesia (IVRA) or Bier block is a common used type of anaesthesia for hand surgery. However, this technique can be associated with some complications, such as local anaesthetic systemic toxicity (LAST). LAST occurs when a large volume of the local anaesthetic is released into the systemic circulation due to the deflation of the tourniquet. The use of a forearm tourniquet (mini-Bier block) instead of the conventional (upper arm) IVRA technique can possibly decrease this risk due to a lower dosage of anaesthetic. The purpose of this study was to determine the preferred type between both techniques.

Methods: This is a prospective, randomized, double-blinded, non-inferiority study. 198 patients were scheduled for distal upper extremity surgery (carpal tunnel syndrome, dorsal or volar wrist ganglions, Dupuytren's disease, trigger finger or trigger thumb, or De Quervain tenosynovitis) and were randomized into either the conventional Bier block or the mini-Bier block (1:1 ratio). In the conventional Bier block 40 ml of 0.5% lidocaine was injected into the patient whereas in the mini-Bier block 25 ml of 0.5% lidocaine was injected. The primary endpoint was the quality of the block. Moreover, secondary outcomes were the onset time of the block, the pain score of patients on a Numerical Rating Scale at baseline, at the time of the placement of the block and at the start of the surgery. Furthermore, the quality of the surgical field, intra-operative tourniquet pain score, tourniquet time, time in the operation room, surgical time, and satisfaction of the patient were assessed.

Results: The quality of the block, quality of the surgical field and patient satisfaction showed no significant differences between both types of anesthesia. Furthermore, no significance was obtained for the onset of the block, the tourniquet time, the tourniquet tolerance time, or the NRS-tourniquet pain score.

Conclusion: Our results demonstrate that the mini-Bier block is equally effective in providing regional anaesthesia as the conventional Bier block, while the dosage of the local anaesthetic is reduced to an almost half and non-toxic level.

1. INTRODUCTION

When ambulatory hand surgery needs to be performed, both regional anesthesia (RA) and general anesthesia (GA) are commonly used [1]. General anaesthesia is defined as a complete loss of consciousness. This type of anaesthesia may be accomplished by either inhalational agents or intravenous anaesthetic agents [2]. In contrast, RA only numbs a particular part of the body to relieve pain or to perform surgical procedures. RA includes several types like spinal anaesthesia, epidural anaesthesia, and nerve blocks and is generally used to carry out orthopaedic surgery on the arm, leg, hand, or foot [3]. Another type of RA is intravenous regional anaesthesia (IVRA), which is a technique that is typically used for outpatient hand surgery.

1.1 Intravenous regional anesthesia

The IVRA or Bier block is a valuable anaesthetic technique for upper and lower limb surgeries or manipulations of a short period [4, 5]. Generally, the extremity to be anesthetized is blocked from the circulation. Next, a solution of a local anaesthetic (LA) is intravenously injected into the venous system of a limb [6-8]. This LA causes a reversible loss of nociception [9]. The IVRA technique is currently used by anesthesiologists in clinical practice.

1.1.1 History of the Bier block and the mini-Bier block.

The IVRA, or Bier block, was first used in 1908 by the German surgeon August Bier [10]. Professor Bier used an Esmarch's bandage to create a bloodless operative field [7]. Bier's original technique consisted of the injection of the LA procaine, the first safe injectable LA which was introduced by Einhorn in 1904 [11], with a concentration of 0.25% to 0.5% via an intravenous (IV) cannula, which had been located between two Esmarch bandages (Figure 1) [11, 12]. These bandages were used as tourniquets to separate the arm into proximal and distal components. Next, Bier injected the LA after which he distinguished two types of anaesthesia: between the two tourniquets an almost-immediate onset of "direct" anaesthesia occurred, while distal to the distally placed tourniquet an "indirect" anaesthesia took place after five to seven minutes. Bier discovered that the direct anaesthesia was the consequence of bare nerve endings bathing in the solution of the local anaesthesia. The indirect anaesthesia, on the other hand, was caused by the local anaesthesia being moved to the substance of the nerves via the vasa nevorum. Here, a conduction block originates. Bier determined that two processes of anaesthesia were linked with this technique: peripheral infiltration block and conduction block [8]. Yet, after initial enthusiasm, this procedure was soon forgotten because it was a cumbersome technique, which required the exsanguination with an Esmarch's bandage and an operative procedure to locate the vein [11]. This method also fell into disuse due to the fear of early liberation of LA into the circulation, which could have caused local anaesthetic systemic toxicity (LAST)

and other complications [7]. Finally, it did not take long before the simple and reliable brachial plexus block was established. This method was also responsible for the growing unpopularity of the Bier block [11].

The repolarization of IVRA in 1963 can be ascribed to the anaesthesiologist C. Holmes. He published a series of cases in the journal *Lancet* [13], describing the novel use of lidocaine and introducing some modifications, including a second cuff to control the tourniquet pain. Furthermore, he concluded that the Bier block was a safe and easy method to obtain the analgesia in the limbs and did not require a lot of experience or special training to carry out [7, 11].

***Figure 1: Bier's original technique**. Bier performed this anaesthetic method by the intravenous injection of the local anaesthetic procaine with a concentration of 0.25% to 0.5%. The place of injection was located between two Esmarch bandages that were applied to obtain a bloodless surgical field [11].*

Another technique, derived from the Bier block, is the mini-Bier block. This method was described in 1978 by Rousso [14] and is used during hand surgery. It consists of the placement of the tourniquet on the forearm, which requires the use of a lower dose of LA [11]. This technique is also currently used in daily practice.

1.1.2 Techniques

The IVRA technique is a process that requires several steps and needs to be performed by a trained anesthesiologist (Figure 2). The first step is the insertion of a venous, plastic catheter in the un-anaesthetized hand. In this way, the anaesthesiologist can administer medication before the start or during the surgery as well as emergency medication, calming agents, and IV hydratation. The next step includes inserting a catheter in the venous system on the dorsum of the hand undergoing surgery. Then, a pneumatic tourniquet, which consists of proximal and distal inflatable band, is placed on the

upper operative arm, followed by the elevation of the entire arm for several minutes to tolerate passive exsanguination. This exsanguination is achieved by wrapping an Esmarch's bandage spirally around the arm from the fingertips to the pneumatic tourniquet. Hence, a dry surgical field is obtained. In the next step, the axillary artery is occluded by inflating the proximal cuff of the pneumatic tourniquet to 50-100 mm Hg above the systolic arterial blood pressure (e.g. 300 mmHg). The Esmarch's bandage is then removed. Following this step, the LA solution, usually 30-50 mL of 0.5% lidocaine HCL, is injected via the catheter in the hand undergoing surgery. This procedure is done slowly to avoid disturbance of the venous system. Once the LA solution is injected, the infusion cannula is withdrawn and pressure is applied at the place of the injection. Due to this injection the patient may sense paralysis of the motor functions, insensitivity, tingling and/or burning sensations. Depending on the injected type of LA solution and its concentration, the anaesthetic blockage will require between three to sixteen minutes after onset.

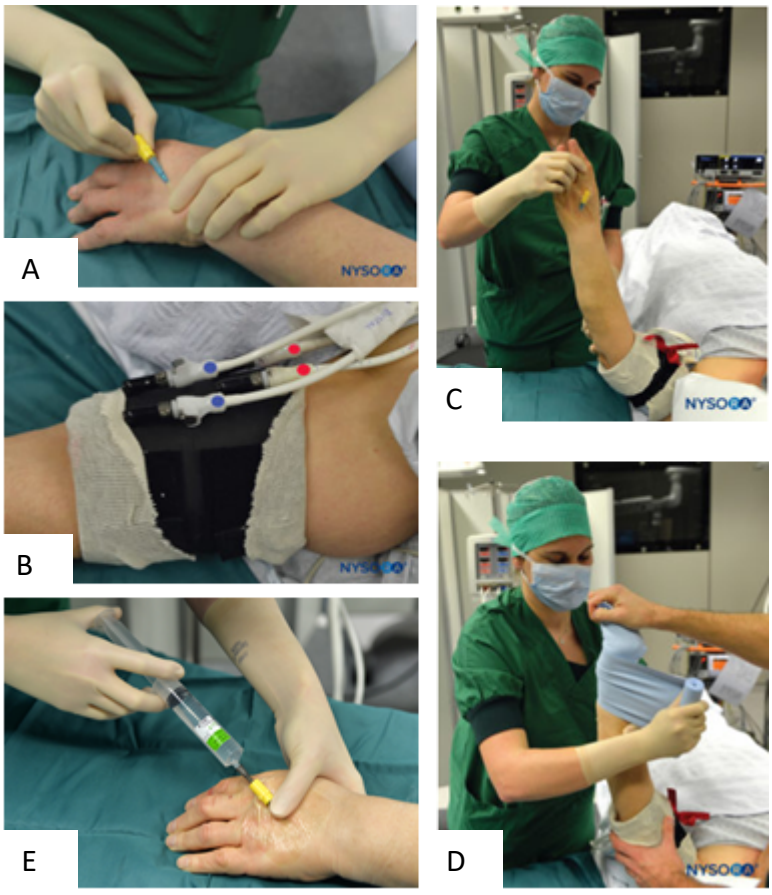

Figure 2: Technique of the conventional Bier block.

A. *The technique for IVRA for upper extremity procedures starts with the placement of an intravenous cannula on the dorsal side of the hand to be anaesthetized.* ***B.*** *Then, a pulmonary tourniquet is applied on the upper arm close to the axilla.* ***C.*** *Next, the extremity is lifted up to allow passive exsanguination.* ***D.*** *An Esmarch's bandage is wound tightly around the limb. The proximal pneumatic cuff inflated and the Esmarch's band is taken off.* ***E.*** *The local anaesthetic is injected via the plastic catheter [8].*

The minimal time required for the cuff to be inflated is 30 minutes. Patients may complain of tourniquet pain or discomfort. This pain can be relieved by inflating the distal band of the tourniquet, followed by the deflation of the proximal band after 30 minutes [6, 8, 15]. About 50% of the LA will then be metabolized or will be trapped in tissues that can set the LA molecules free into the vascular system. When the inflation time would only be around 15 to 20 minutes, the majority of the LA

molecules will not be metabolized or stuck into the surrounding tissues, which can elicit complications in the cardiovascular or neuronal system. The sensation in the anaesthetized hand and arm returns rapidly once the tourniquet is deflated [6, 15]. The motoric functions usually recover between two to eight minutes, indicating that the binding of the LA molecules is not very stable [16]. The success rate of the IVRA technique, if carried out appropriately, lies between 96 and 100% [17, 18]. Nevertheless, it is still possible that a complete blockade is not achieved. Various reasons can cause failure of the Bier block method, including the lack of checking equipment before surgery, failure to create a bloodless field, or poor functioning of the pneumatic double tourniquet [15]. In conclusion, IVRA is a technique that is frequently used by anaesthesiologists due to its ease and reliability.

The advantages of different tourniquet techniques were the subject of several studies. A recent trend is the application of a forearm tourniquet, also called the mini-Bier block. This method includes the placement of a tourniquet distal to the elbow and requires lower dosages of LA to achieve sufficient anaesthesia and analgesia (Figure 3). In practice, the use of forearm tourniquet has proven to be a secure and valid alternative to a conventional Bier block. Yet, the mini-Bier block has the disadvantage that it can interfere with the operative field if the tourniquet is placed too distal. Benefits of this technique include the reduction of LA from 40 ml of Lidocaine to nearly 25 ml, which is a non-toxic dosage. Moreover, tourniquet pain is less in the mini-Bier block than in the regular Bier block [5, 19].

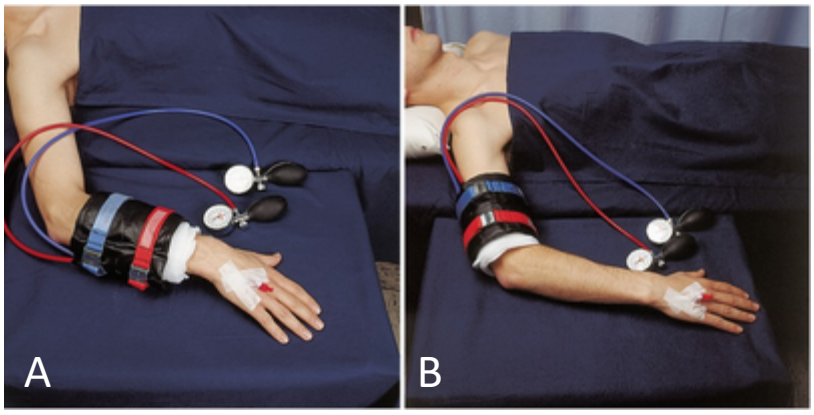

Figure 3: Types of Intravenous regional anesthetics used in the study. A. *Forearm (mini)- Bier block requires 25 ml of 0.5% lidocaine;* ***B.*** *Conventional upper arm Bier block requires 40 ml of 0.5% lidocaine [20].*

1.1.3 Complications of the conventional Bier block and the mini-Bier block

Although the conventional Bier block is a safe method to use, one should be aware of the possible complications that can occur [5]. These complications can be divided in drug related side effects and equipment related side effects. The drug-related side-effects depend on the type of LA that was administered intravenously to the patient, while equipment-related complications are associated with

the materials and techniques that were used to separate the vessels of the extremity from the systemic circulation.

Lidocaine is the LA that is mostly administered during IVRA and therefore, most reported side-effects are associated with lidocaine. A high concentration of lidocaine in the plasma of the patient results in peripheral vasodilation and a reduced contractility of the heart. Therefore, the tourniquet should not be released until a minimum of 30 minutes has passed after the injection of the LA. However, the tourniquet itself can also elicit ischemic pain and irritation [8]. A possible solution can be the use of a double tourniquet. First, the distal cuff is inflated. Second, the proximal band is deflated. This method will relieve the patient from a continuous pressure on the same place of the arm. In case this does not relieve the pain, additional sedative medications can be administered intravenously in order to ease the patient's comfort. Other adverse effects that have been reported are pre-ictal attitude, seizures, cardiac arrest, damage of the nerves, discoloration of the skin, petechiae, thrombophlebitis, compartment syndrome, and LAST [5].

The possibly lethal adverse reaction LAST may occur after the administration of LA. The IVRA method is associated with a notable risk of serious complications [21]. Symptoms of this adverse reaction include tinnitus, perioral numbness, seizures, and cardiovascular failure [8]. The appearance of LAST is variable, but the classic progression begins with excitement of the central nervous system (CNS), for example the taste of metal in the mouth, audiovisual changes, confusion, and agitation. Eventually, seizures, CNS depression and toxicity of the heart will evolve (i.e. conduction disruption, myocardial dysfunction, and lability of the peripheral vascular tone) [21-23]. The occurrence of LAST is dependent on several risk factors, including the total dose of the LA and patient characteristics. The correct dose of LA is the lowest dose that obtains the desired period of analgesia or anaesthesia. It has been shown that elderly people as well as neonates and infants are at greater risk to develop LAST. Furthermore, pregnant women or patients with a renal, cardiac, or hepatic disease also have an increased risk for LAST. As for the IVRA technique, LAST can appear when the tourniquet is inflated and up to 30 minutes after the band has been removed. In order to prevent the occurrence of LAST, the modifiable risk factors need to be targeted. Therefore, prevention is a multifactorial process and can be executed using ultrasound-guided nerve blockades and restricting the drug dosage (e.g. the mini-Bier block) [21].

1.1.4 Advantages and disadvantages of conventional Bier block and the mini-Bier block.

The biggest advantages of the conventional IVRA technique are that it is a simple, rapid, safe, and reliable method to obtain RA, when performed correctly. The success rate amounts 96-100% and there is only a low incidence of technical failure. Moreover, it generates a bloodless surgical field, which makes it suitable for short-term operations. Normal sensation and motor power return rapidly after

the release of the tourniquet. An early outpatient discharge is facilitated due to the rapid recovery [11, 24]. Unfortunately, the fast dissipation of the block leads to postoperative pain. Other limitations of the regular Bier block include ischaemic tourniquet pain, systemic toxicity and the need for exsanguination [11]. The use of a forearm cuff allows the dosage of LA to be lowered to almost half of what is needed for the upper arm method [24]. Furthermore, it has been proposed that a forearm tourniquet causes less ischemic pain. Hence, it can be tolerated longer and less additional analgesia is required [19]. This also increases the time available for the surgery [25]. Finally, the mini-Bier block allows the preservation of motor function of the long flexors and extensors of the hand during the period of anaesthesia [10, 26]. Although it is promising technique, forearm IVRA is still not routinely applied because of the potential risk of an incomplete occlusion of the interosseous vessels during surgery. This incomplete occlusion may generate an insufficient hemostasis, leakage of LA into the circulation, and an increased risk of nerve injuries [19, 24].

1.2 Types of hand surgery

The IVRA method using LA is applicable for short surgeries (up to 1 hour) on the extremities. It is, therefore, most appropriate for surgery of peripheral, soft tissues such as carpal tunnel syndrome and Dupuytren's contracture disease [8]. In the light of this study, the following types of hand surgery will be discussed: Carpal Tunnel syndrome (CTS), Trigger finger and Trigger thumb, Dupuytren's disease, dorsal and volar wrist ganglions, De quervain tendosynovitis.

1.2.1 Carpal tunnel syndrome

The CTS is the most frequent type of nerve entrapment neuropathies. These neuropathies are characterized by a damaged nerve at places where it runs through a narrow, closed area. The CTS specifically is induced by the compression of the median nerve, running through the osteofibrous canal, also called the carpal tunnel, in the region of the wrist. This canal encloses the bones of the wrist, the transverse carpal ligament, the median nerve, and the digital flexor tendons (Appendix I). Factors that deteriorate this condition and sometimes cause pain are oedema, inflammation of the tendon, hormonal changes and manual labor. Severe cases are presented as a weakness of the muscles, innervated by the median nerve. This also results in hand weakness. Women with a mean age of diagnosis of 50 years are mostly affected by CTS. Possible risk factors are diabetes mellitus, obesity, hypothyroidism, menopause, pregnancy, and arthritis. Several non-surgical treatments are available, such as laser therapy, local corticosteroid injections, and therapeutic ultrasound. Surgical treatment consists of the release of the content of the carpal tunnel by cutting the transverse carpal ligament [27].

1.2.2 Dupuytren's disease

Dupuytren's disease is a common and progressive fibro-proliferative condition of the palmar and digital fascia of the hand. In the Western world it affects 12% of the 55 years old population and up to 29% of the people with an age of 75. First, a firm nodule appears in the hand. This nodule then expands to fibrous collagenous cords that extend into the fingers. The progression of this disorder is variable and characterized by the maturation, thickening, and contraction of these cords, which causes permanent flexion deformities (Appendix II). Of all patients, 20 to 40% develop some grade of flexion deformity, which prevents normal functioning of the hand (i.e. self-care and employment). When the digital flexion contractures limit the use of the hand, a surgical intervention is necessary consisting of the division of the cords with needle fasciotomy or excision of the collagen [28].

1.2.3 Dorsal and volar wrist ganglions

Ganglion cysts are synovial cysts that can develop near any joint or tendon sheath in the body (Appendix III). They are filled with a gelatinous mucoid substance. These cysts are generally located around the wrist, but are also encountered in the knee or foot [29, 30]. Cysts are believed to result from repetitive micro-injury of the connective tissue, which then degenerates to a mucinous, jelly-like material. Approximately 70% is found on the dorsal side of the wrist while 20% is located on the volar part of the wrist. The remaining 10% arises from other various places of the body. Ganglion cysts appear to be most common in women aged 20 to 50 years. Women are three times more predisposed for cysts than men. Although these lumps are mostly asymptomatic, possible symptoms include pain and weakness of the wrist. Nevertheless, some patients may prefer treatment because of the unpleasant cosmetic appearance. Wrist cysts can grow up to one to three cm in size. Dorsal wrist ganglions can be treated non-surgically via aspiration, which is not recommended for volar wrist ganglion cysts due to their proximity to the radial artery. Surgical excision is indicated for patients with recurring symptoms who have failed conventional management [29].

1.2.4 Trigger finger and trigger thumb

Trigger finger, or stenosing flexor tenosynovitis, is one of the most frequent causes of hand dysfunction in adults (Appendix IV). This disorder is more prevalent in patients between 40 to 60 years and is mostly found in the dominant hand, specifically the fourth digit. Children under the age of eight years are most commonly affected and boys and girls are equally susceptible for this condition, especially for trigger thumb. When patients flex a finger, the flexor tendon runs through several sheats: the annular and cruciform pulleys. These sheats encapsulate the tendon to keep it attached to the bone in the flexed form of the finger. Furthermore, the tendon can slide smoothly back and forth during flexion and extension [31]. In case of a trauma or when overuse, compression forces, or repeated gripping maneuvers, occur to the finger, tendon hypertrophy and sheath limitation appears. This prevents the

smooth sliding of the tendon through the sheat, causing the sensation of a “caught” or “locked” finger [31, 32]. Diabetes mellitus, amyloidosis, and rheumatoid arthritis are typical examples of predisposal diseases for this condition [32]. Trigger finger and trigger thumb can be treated noninvasively (i.e. massage, heat, and/or ice, with corticosteroid injections (which may give relief for up to ten years), and with shock wave therapy) or with open surgery [31].

1.2.5 De Quervain’s tenosynovitis

De Quervain’s tenosynovitis affects the abductor pollicis longus (APL) and the extensor pollicis brevis (EPB) tendons, which run through the first dorsal section of the wrist (Appendix V). This condition results from repetitive and continued pressure of the APL and EPB tendons as they pass through a swollen extensor retinaculum. Symptoms are pain and inflammation in the area of the radial styloid, which can be deteriorated with movement and exercise requiring ulnar deviation with a clamped fist and thumb metacarpophalangeal joint flexion, for example by wringing a washcloth. The type of treatment is based on the severity of the disease and includes anti-inflammatory medication, corticosteroid injections, occupational therapy, or a surgical intervention [33].

1.3 Lidocaine

Lidocaine is an amide LA. The action mechanism of lidocaine interferes with the sodium ion channels inside the nerve cells. The uncharged molecule diffuses through the neural sheats into the axoplasm. Next, this molecule combines with hydrogen ions and ionizes. This cation attaches reversibly to the inner side of the sodium channels, resulting in the blockage of these open stated channels. Nerve depolarization is consequently prevented (Appendix VI). Lidocaine is a weak base with a dissociation constant (pKa) of 7.7. At a pH of 7.4, 25% of this LA will be un-ionized and can translocate within the nerve cells. This indicates that lidocaine has a faster onset time in comparison with other LA with higher pKa values [34].

1.4 Objectives

This prospective, randomized, controlled, researcher-blinded non-inferiority, mono-center study aimed to compare two commonly used IVRA techniques for distal upper extremity surgery: the Bier block and the mini-Bier block, in order to investigate the preferred type. We hypothesized non-inferiority of the mini-Bier block compared to the conventional Bier block. The primary outcome of this prospective study was the quality of the blockade. Secondary outcomes included the onset time of the block, the pain score of patients on a Numerical Rating Scale (NRS, with 0=no pain and 10=worst imaginable pain (Appendix VIII)), the quality of the surgical field, intra-operative tourniquet pain score, tourniquet time, time in the operation room, surgical time, and satisfaction of the patient.

2. METHODS

2.1 Clinical Study Design

The present trial was designed as a prospective, randomized, controlled, researcher-blinded, non-inferiority study to compare two types of anaesthesia in patients undergoing hand surgery. Patients were divided into two groups; group I: patients undergoing surgery with the conventional Bier block as anaesthetic technique, and group II: patients undergoing surgery with the mini-Bier block as anaesthetic technique. This is a mono center study in which all patients were included at the Jessa Hospital (campus Virga Jesse or Salvator, Hasselt, Belgium) between November 2018 and June 2019. Both techniques (conventional Bier block and mini-Bier block) are actively used techniques in the Jessa Hospital. The Ethics committee of the Jessa Hospital approved the study. The study was registered at ClinicalTrials.gov (ClinicalTrials.gov registry number: NCT03761329) and was conducted according to the declaration of Helsinki.

2.2 Patients

The study population included 280 patients undergoing hand surgery under regional anaesthesia. More specifically, patients treated for the release of carpal tunnel syndrome, triggerfinger and –thumb, dequervain tenosynovitis, Dupuytren's disease or resections of a wrist cyst were potential volunteers.

2.2.1 Inclusion criteria

Several inclusion criteria needed to be fulfilled for the present study. The participating patients had to be 18 years or older, had an American Society of Anesthesiologists (ASA) classification (Appendix VII) of I, II or III, and had to undergo hand surgery where a regular Bier block and mini-Bier block could be applied. Finally, the written informed consent (IC) needed to be signed by the patients that participated in the study.

2.2.2 Exclusion criteria

Patients were excluded based on the following criteria: refusal of the patient, any age younger than 18 years, participation in another clinical or pharmaceutical trial or trials with medical devices, previous randomisation in this trial, undergoing the surgical procedure with sedation or general anaesthesia, bilateral hand surgery, a BMI (Body Mass Index) equal to or higher than 40 kg/m^2, having a neurological disease, chronic pain symptoms, the use of opioids in the past month, diabetes mellitus with nerve/organ damage as a result (advanced diabetes mellitus), allergy or hypersensitivity to local anaesthetics, blood clotting disorders, language barrier and/or the inability to understand the study procedure.

2.2.3 Recruitment

Recruitment of the eligible patients was performed at the day care unit before undergoing surgery at the Jessa Hospital. Oral and written information concerning the study was provided to all patients and all patients had the opportunity to ask questions concerning the study. Recruitment was completed once patients signed the IC form. All patients were in accordance with the inclusion- and exclusion criteria.

2.2.3.1 Randomization

Patients were randomized in the two groups (group I received the conventional Bier block and group II received the mini-Bier block) in a 1:1 ratio. Researchers and the surgeon were blinded to the anaesthesia technique in order to assess pain as well as the quality of the blockade and the quality of the chirurgical field (bloodless field). The unblinded anaesthesiologist received a sealed envelope containing the anaesthesia technique together with a specific randomization code which was provided to the investigator to link the used type of anaesthetic with the correct patient.

2.3 Study procedure

2.3.1 Pre-operative

Baseline demographic data such as age, gender, ASA score, side of surgery, and type of hand surgery were collected. Furthermore the pain score on Numerical Rating Scale (where 0= no pain and 10= worst imaginable pain (Appendix VIII)), was scored before surgery. The time of patient entry in the operating room (OR) was noted. Every patient received one gram paracetamol intravenously before the surgery, as well as standard monitoring and an IV infusion with NaCl 0.9% in the contralateral arm. To remain blinded, the surgeon and the researcher were asked to leave the surgery room for five minutes before the anaesthesia technique was performed preoperatively. Next, an IV access route was created on dorsal surface of the hand that required surgery. Via this route the local anaesthetic could be injected. Next, the hand and arm were exsanguinated with an Esmarch's bandage to obtain a bloodless operative field. The tourniquet was placed on the upper arm for the regular Bier block, and on the forearm for the mini-Bier block. Finally, the anaesthetic solution consisting of 40 ml 0.5% linisol (B. Braun Medical N.V., Melsungen, Germany) for the regular Bier block or of 25 ml 0.5% linisol for the mini-Bier block was administered intravenously. The NRS-pain score was assessed when the anaesthesia technique was performed. Finally, the onset time of the blockade was determined after five minutes via the pin prick test with a small injection needle (BD Microlance™ 3, 23G1"- Nr. 16, Becton Dickinson S.A, Fraga, Spain). This was the time required between the placement of the anaesthetic blockade and the disappearance of the sensory feeling in the hand. Rescue medication was administered if no sensory blockade had occurred 10 minutes after the placement of the

anaesthetic technique. This rescue medication consisted of 0.5 mg alfentanil or 1cc rapifen, followed by a local injection of 2% lidocaine in case of incomplete blockade. This was repeated one time when no sensory block occurred. Finally, in case no block occured after the described rescue medication was given, diprivan (titration per 1 cc) was administrated and, if necessary, conversion to GA was carried out.

2.3.2 Per-operative

The full operative procedure was timed. Start time of the surgery was defined when the surgeon made the first incision. Immediately, the NRS-pain score of this incision was asked. Furthermore the NRS-pain score of the tourniquet was asked 10, 15, 20, 25, and 30 minutes after the placement of the anaesthetic technique. Tourniquet toleration time was noted when the NRS-pain score of the tourniquet was higher than three. The surgical end time was defined when the last stitch to close the wound was made.

2.3.3 Post-operative

The tourniquet needed to be kept on for a total tourniquet time of 25 minutes (regular Bier block) or 10 minutes (mini-Bier block) in order to prevent postoperative LAST. The 'tourniquet time' stopped when the tourniquet was deflated and the 'time in the operation room' was stopped when the patient left the surgical room. The quality of the blockade (grade 1: complete motor and sensory block; grade 2: partial motor blockade, no pain or deep pressure sensitivity; grade 3; partial motor blockade, mild pain with need for local or opioid rescue medication; grade 4: incomplete motor and sensory blockade with the need for sedation or conversion to GA) was scored by the blinded surgeon. Blinding was accomplished by applying both tourniquets (upper arm and under arm) to the arm, but only one was inflated. Finally, the blinded surgeon was asked to evaluate the quality of the surgical field, based on a five points scale (unacceptable, bad, moderate, good, excellent).

2.3.4 One day post-operative

Twenty four hours after the surgery, the patient's satisfaction of the used anaesthesia technique was assessed on the seven point Likert scale with number one being extremely dissatisfied and number seven being extremely satisfied. The flow chart of the study procedure is visualised in figure 4.

2.4 Data collection

2.4.1 Study endpoints

The primary outcome of this study is the quality of the blockade for both the regular and the mini-Bier block. The term "quality" was assessed by the surgeon as "complete" or "incomplete". A complete blockade includes grade 1 (complete motor and sensory block) and grade 2 (partial motor blockade,

no pain or deep pressure sensitivity). An incomplete blockade is subdivided in grade 3 (partial motor blockade, mild pain with need for local or opioid rescue medication) and grade 4 (incomplete motor and sensory blockade with the need for sedation or conversion to GA). Several secondary outcomes were also checked. They included the onset time, which was the time measured from the administration of the local anaesthetic until the sensory blockade occurred. This onset time was assessed with the use of a pin prick test, where the place of incision on the hand was touched with a needle from five minutes after injection of the LA. This was repeated every minute in case the patient still sensed the sharpness of the needle, until ten minutes after the injection of the LA. Rescue medication was given to the patient if no sensory blockade was present after 10 minutes. Other secondary outcomes were the pain scores, measured with the 11-point NRS-pain score. Furthermore, the tourniquet time and tourniquet-toleration time, the quality of the surgical (bloodless) field, time in the operation room, and surgical time were assessed. Finally, the patient satisfaction was asked 24 hours postoperative with the "seven-point Likert scale" (with 1=very dissatisfied and 7=very satisfied).

2.5 Statistics

2.5.1 Sample size

Sample size was determined according to the primary outcome of this study. We expected a 98.5% complete blockade in the mini-Bier block group and a 100% complete blockade in the Bier-block group, based on a meta-study (9). A power calculation was performed (α= 0.05, power=0.80 and drop-out ratio = 3.5%) and stated that 140 patients need to be included in each group to obtain a significant result. Statistical analysis was performed on the primary outcome and the secondary outcomes of each group and then compared.

2.5.2 Statistical analysis

Statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) 24.0 (IBM, Chicago, IL). A p-value less than 0.05 was considered statistically significant. Descriptive statistics were shown as the frequencies and percentages of the total patients in categorical variables. Numeric variables were presented as the mean with its variance. Comparisons between the groups were tested with a Chi-square test for frequencies (or Fisher's exact test). Normality was tested using the Shapiro-Wilk test. A Mann-Witney U test was used for not normally distributed numeric variables. A student t-test was used for normally distributed numeric variables. A repeated measures correction was applied on the analysis in order to correct for the repeated measurements of the NRS pain-score. A mean difference of 1.3 points or more on the NRS pain-score was accounted as a clinically relevant result. Statistical significance is defined as a p-value of less than or equal to 0.05. A p-value of less than or equal to 0.10 will be considered as a trend.

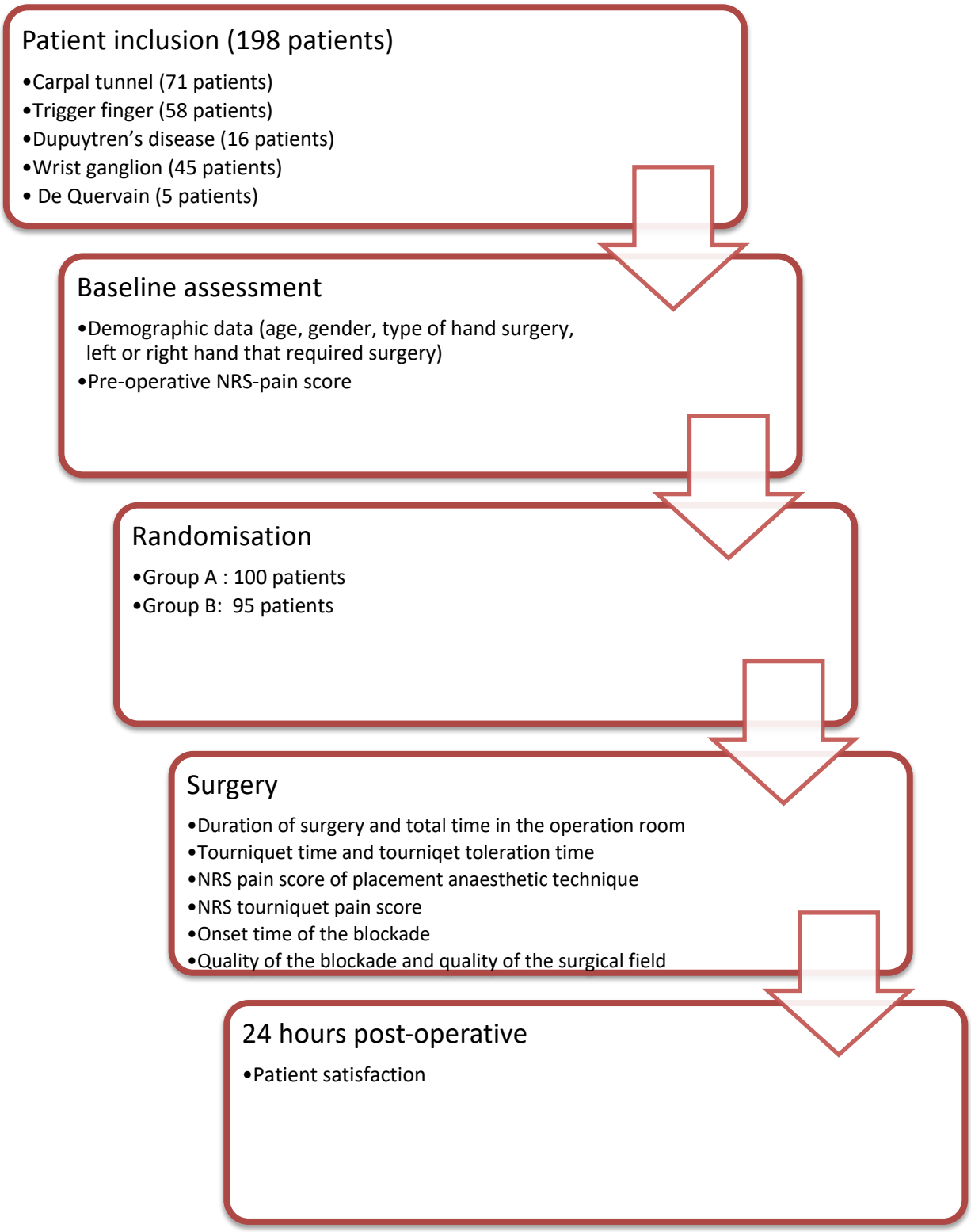

Figure 4: Flow-chart for the study procedure. *NRS: numeric rating scale*

3. RESULTS

3.1 Flow of participants

From November 2018 until May 2019, 198 patients were included in this study. In total, 261 patients were approached to participate in the study. Sixty three patients did not participate, assessment for their eligibility lead to several reasons of screening failure: 45 patients met exclusion criteria (mainly insufficient understanding of Dutch, chronic pain and/or use of opioids, and request for sedation or GA), 17 patients declined to participate, and one patient was excluded for another reason (disorganisation study researcher). Eventually, 198 patients gave consent for participation and were randomly allocated to group A (n = 100) or group B (n=95) and received the assigned anaesthesia technique (regular Bier block or mini-Bier block). This prospective, randomized, controlled, researcher-blinded non-inferiority study is still on going. In order to maintain investigator- and surgeon blinding, the two treatment groups are analysed as “Group A” and “Group B”. Three out of 198 patients, two patients of group A and one patient of group B, did not receive the allocated anaesthesia technique due to violation of the study protocol (Inability to perform block placement (perforation hand veins), and tourniquet release right after block placement (appearance of LAST symptoms)). The flow of participants is visualized in a flow diagram designed following the Consolidated Standards of Reporting Trials (CONSORT) statement (Figure 5).

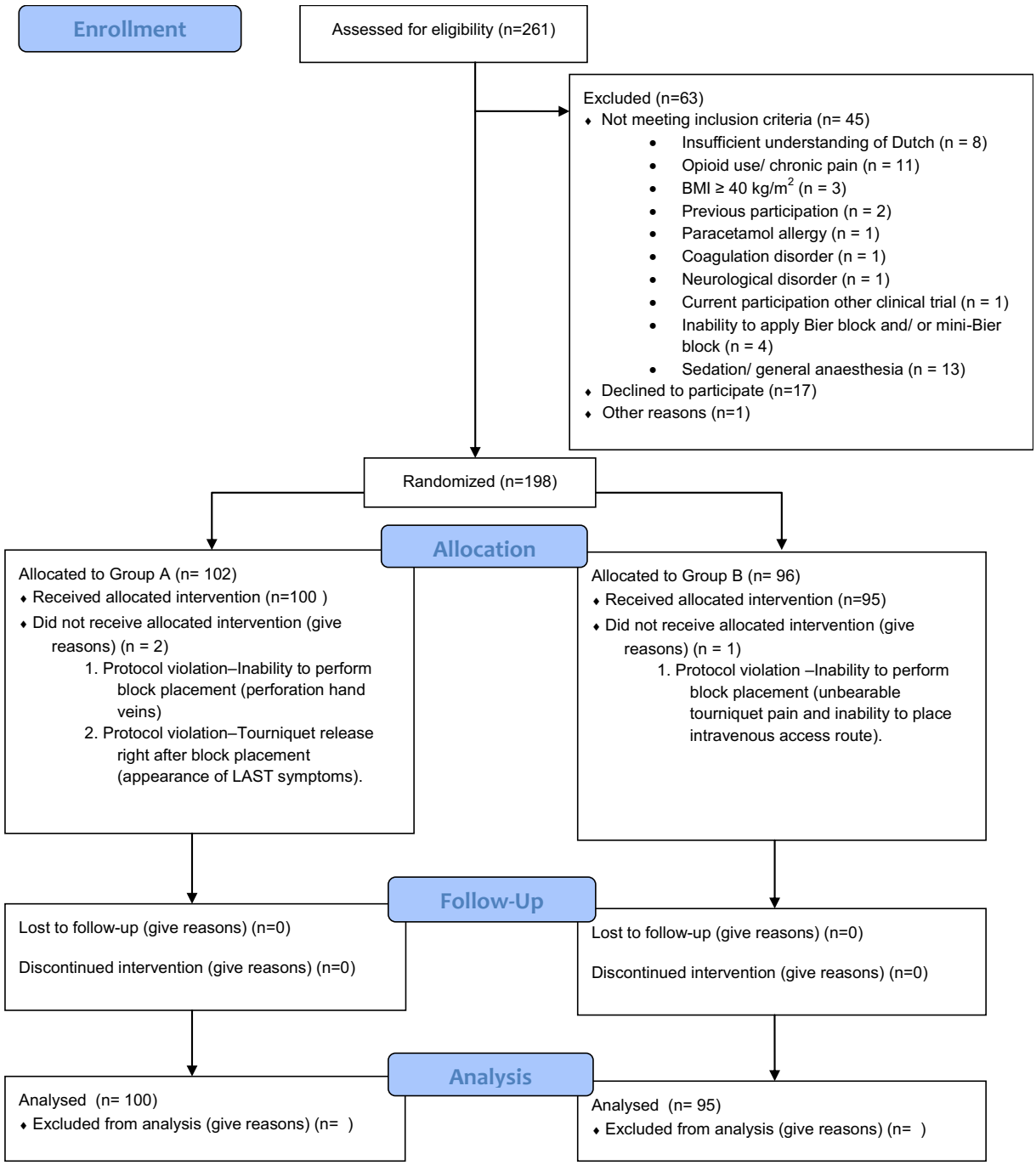

Figure 5: CONSORT diagram. *The flow of participants through the randomized trial is represented in a flow diagram. BMI: Body Mass Index.*

3.2 Patient characteristics

Patients in the two study groups were similar with respect to demographic and surgical characteristics at baseline (Table 1). So, both groups were equal in proportion (p-value>0.05).

Table 1. Demographic and surgical characteristics of the patient

Variable		Total study population (n = 195)	Group A (n =100)	Group B (n=95)	p-value*
Age	Years	58.00 (18-91)	59.00 (18-91)	57 (19-87)	0.904[b]
Gender	Male/female	86/109 (44.1%/55.9%)	45/55 (45%/55%)	41/54 (43.2%/56.8%)	0.796[c]
Location of surgery	Right/left	108/87 (55.4%/44.6%)	51/49 (51%/49%)	57/38 (60%/40%)	0.206[c]
Type of surgery	Carpal tunnel syndrome	71 (36.4%)	36 (36%)	35 (36.8%)	0.958[c]
	Trigger finger and/or trigger thumb	58 (29.7%)	29 (29%)	29 (30.5%)	
	Dupuytren's disease	16 (8.2%)	8 (8%)	8 (8.4%)	
	Dorsal or volar wrist ganglion	45 (23.1%)	25 (25%)	20 (21.1%)	
	De quervain tenosynovitis	5 (2.6%)	2 (2%)	3 (3.2%)	

*p<0.05 is considered significant

Data are given as median (IQR) or as absolute numbers (percentage of the total subjects). P-values were obtained with the Mann-Whitney U[b] test and the Pearson chi-square[c] test.

3.3 Primary outcome

The primary outcome for this study is the quality of the block, outlined in table 2 and visualized in figure 6. No significant difference concerning the quality of the block (grade 1: complete motor and sensory block; grade 2: partial motor blockade, no pain or deep pressure sensitivity; grade 3; partial motor blockade, mild pain with need for local or opioid rescue medication; grade 4: incomplete motor and sensory blockade with the need for sedation or conversion to GA) was found between group A and group B (p-value>0.05). When the quality of the block was defined as complete (grade 1 and grade 2) and incomplete (grade 3 and grade 4), again no significant difference was observed (p-value>0.05). In 76% and 80% of the patients in group A and group B, respectively, a complete anaesthesia block was obtained.

Table 2. Primary outcome of the study: quality of the block.

Variable		Group A (n = 100)	Group B (n=95)	p-value*
Quality of the block	Grade 1[a]	23 (23%)	19 (20%)	0.619
	Grade 2 [a]	53 (53%)	57 (60%)	
	Grade 3 [a]	23 (23%)	19 (20%)	
	Grade 4 [a]	1 (1%)	0 (0%)	
	Complete/ incomplete[b]	76/24 (76%/24%)	76/19 (80%/20%)	0.501

[a](grade 1: complete motor and sensory block; grade 2: partial motor blockade, no pain or deep pressure sensitivity; grade 3; partial motor blockade, mild pain with need for local or opioid rescue medication; grade 4: incomplete motor and sensory blockade with the need for sedation or conversion to GA).

[b](Complete = grade 1 + grade 2, incomplete = grade 3 + grade 4)

*p<0.05 is considered significant

Data are given as as absolute numbers (percentage of the total subjects). P-values were obtained with the Pearson Chi-Square test.

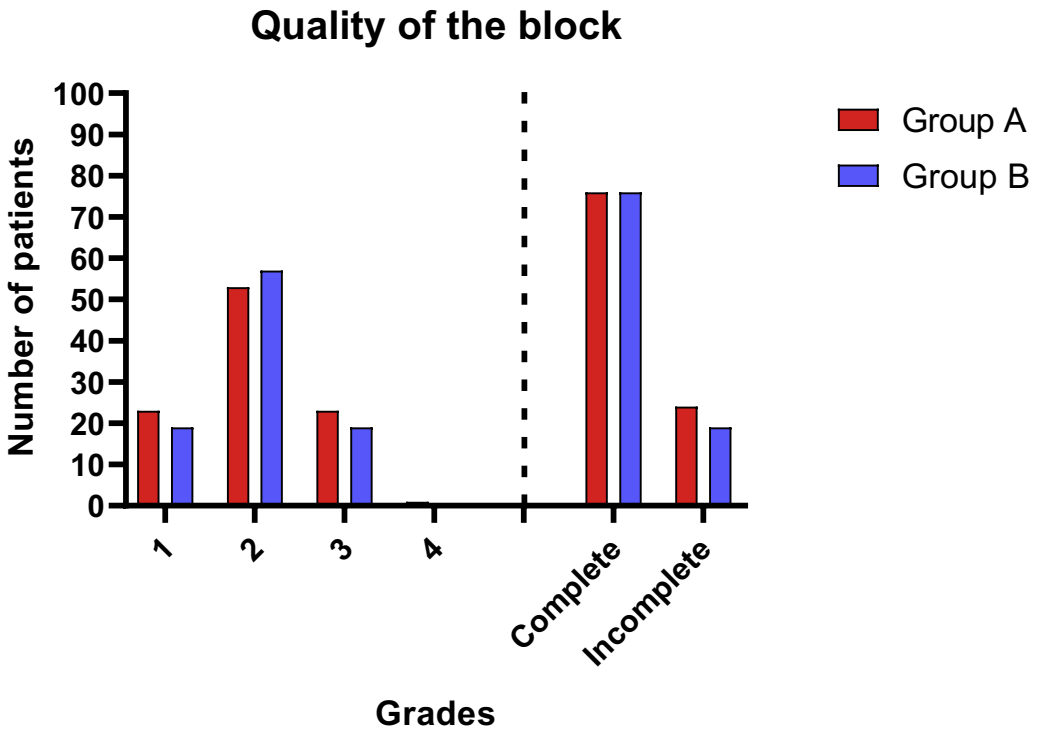

Figure 6: Quality of the block: *the primary outcome of the study can be divided into four grades (1= complete motor and sensory block, 2=partial motor blockade, no pain or deep pressure sensitivity, 3=partial motor blockade, mild pain with need for local or opioid rescue medication, 4=Incomplete motor and sensory blockade with the need for sedation or conversion to GA). Group A and group B are comparable in all four grades (left). A distinction was also made between complete (grade 1 + grade 2) and incomplete (grade 3 + grade 4) and showed overall the same number of patients for both group A and group B (right).*

3.4 Secondary outcomes

3.4.1 Quality of the surgical field

The quality of the surgical field, assessed by the surgeon, is defined into 5 grades: unacceptable, bad, moderate, good, and excellent and showed no significant difference between both treatment groups (p-value=0.377, Table 3 and Figure 7). The median score both group A and group B is four, which means a "good" workable surgical field.

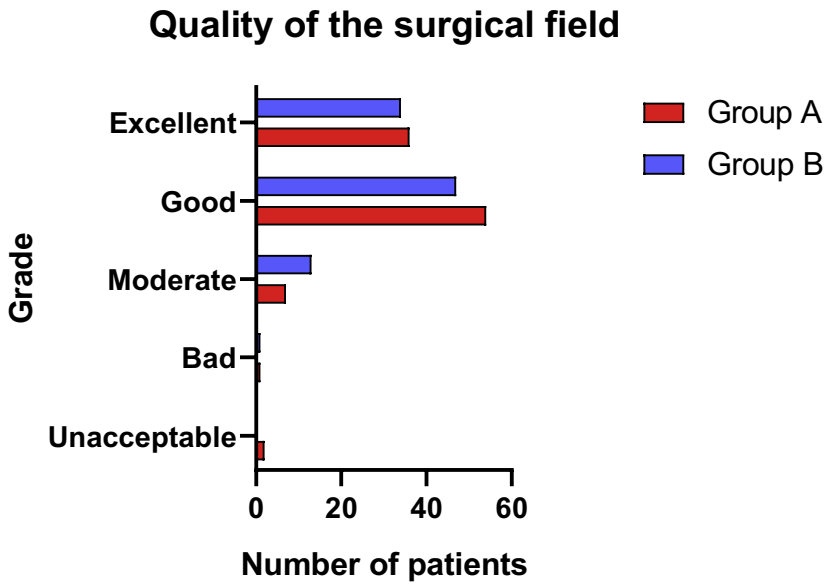

Figure 7: Quality of the surgical field: *this secondary outcome can be divided into 5 grades: unacceptable, bad, moderate, good, and excellent. Two of 195 patients had an unacceptable surgical field in group A, while this was zero for group B. Other grades were comparable between both groups. The most frequent surgical field was assessed as 'good' in both group A and B.*

3.4.2 Patient satisfaction

Patients were satisfied about the type of anaesthesia they received for their surgery. No significant difference was detected in satisfaction between both groups (p-value=0.408, Table 3 and Figure 8).

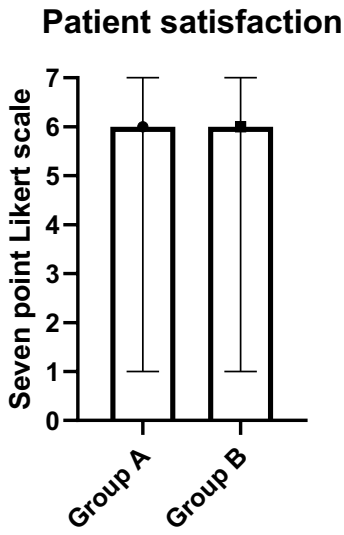

Figure 8: Patient satisfaction: *This secondary outcome was assessed on the seven point Likert scale (0=very unsatisfied and 7=very satisfied) and showed a median score of 6 and an interquartile range between 0 and 7 for both group A and group B.*

Table 3: Secondary outcomes: quality of the surgical field and patient satisfaction.

Variable		Group A (n = 100)	Group B (n=95)	p-value*
Quality of the surgical field	Unacceptable	2 (2%)	0 (0%)	0.377
	Bad	1 (1%)	1 (1.1%)	
	Moderate	7 (7%)	13 (13.7%)	
	Good	54 (54%)	47 (49.5%)	
	Excellent	36 (36%)	34 (35.8%)	
Patient satisfaction	1[a]	1 (1%)	2 (2.1%)	0.408
	2[a]	0 (0%)	2 (2.1%)	
	3[a]	4 (4%)	5 (5.3%)	
	4[a]	8 (8%)	3 (3.2%)	
	5[a]	16 (16%)	11 (11.6%)	
	6[a]	23 (23%)	28 (29.5%)	
	7[a]	42 (42%)	40 (42.1%)	
	Missing values	6 (6%)	4 (4.2%)	

[a]Seven point Likert scale (1= extremely dissatisfied and 7 = extremely satisfied)
*p<0.05 is considered significant
Data are given as as absolute numbers (percentage of the total subjects). P-values were obtained with the Pearson Chi-Square test.

3.4.3 NRS-pain scores

NRS-pain scores were assessed at several time points during the study and are represented in table 4. The baseline pain score was asked prior to the surgery. There was no significant difference between group A and B (1 (0-8) vs 0 (0-8); p-value=0.272). The pain score asked at the time of placement of the anaesthetic blockade showed a higher median value for both groups than the baseline pain score but again did not differ significantly between group A and B (4 (0-10) vs 3 (0-9); p-value=0.203). The NRS-pain score assessed at the beginning of the surgery had comparable results for the both groups, with a median value of zero and a range from zero to eight for group A and from zero to ten for group B. Finally, the NRS-pain score of the tourniquet was assessed after 10, 15, 20, 25, 30 minutes. No significance differences were found at these time points between group A and group B (p-values= 0.168, 0.269, 0.863, 0.123, 0.656). In both groups the pain score increases slightly while the tourniquet time progresses. A repeated measures Anova with Bonferroni correction was used to assess and correct for the repeated NRS-pain score measurements and to determine if there is an interaction between the group and three time points of the NRS-pain score (Figure 9). A significant difference was found between the two groups in the course of the measured time (P-value=0.019 (data not shown)). The output of group A revealed that there was a slight increase in NRS-pain score from baseline to NRS-pain score provoked by the anaesthesia (1.81±2.289 vs 3.98±2.825, respectively), which was statistically significant (p-value=0.000). Moreover, in group A, a significant difference was found between the NRS-pain score of placing the anaesthesia technique and the NRS-pain score at the start of the surgery (3.98±2.825 vs 1.63±2.239, respectively; p-value=0.000). However, between the NRS-pain score at baseline and the NRS-pain score at the start of the surgery no significance was obtained for group A (1.81±2.289 vs 1.63±2.239, respectively; p-value=1.000). The same applies to group B, where a significant difference was found between the NRS-pain score at baseline and the NRS-pain score provoked by the placement of the anaesthesia technique (2.19±2.566 vs 3.10±2.485, respectively; p-value=0.010). The output of group B also showed that there was a decrease in NRS-pain score provoked by the placement of the anaesthesia technique and the NRS-pain score at the start of the surgery (3.10±2.485 vs 1.62±2.291, respectively), which was significantly different (p-value=0.000). Yet, no significance was found between the NRS-pain score at baseline and the NRS-pain score at the start of the surgery (2.19±2.566 vs 1.62±2.291, respectively; p-value=0.261).

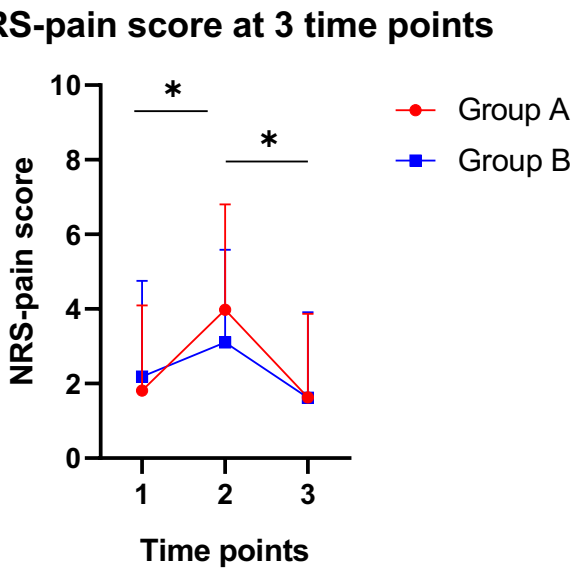

***Figure 9**: **NRS-pain scores at 3 time points.** The NRS-pain score was assessed at three different time points (1= NRS-pain score at baseline, 2= NRS-pain score provoked by the anaesthesia, and 3= NRS-pain score at the start of the surgery). Mean and standard deviation are plotted for each group at each time point (Group A: 1: 1.81±2.289; 2: 3.98±2.825; 3: 1.63±2.239; Group B: 1: 2.19±2.566; 2: 3.10±2.485; 3: 1.62±2.291).* *p-value<0.05

Table 4: Secondary outcomes: NRS-pain scores

Variable		Group A (n =100)	Group B (n=95)	P-value*
NRS pain score at baseline	0-10[a]	1 (0-8)[b]	0 (0-8)	0.272
NRS pain score of placement anaesthetic blockade	0-10[a]	4 (0-10)	3 (0-9)[c]	0.203
NRS pain score at first incision	0-10[a]	0 (0-8)[b]	0 (0-10)	0.051
NRS tourniquet pain score at:	0-10[a]			
• **10 min**		2 (0-10)[d]	3 (0-10)	0.168
• **15 min**		2.5 (0-10)[e]	3 (0-10)	0.269
• **20 min**		3.5 (0-10)[f]	4 (0-10)[g]	0.863
• **25 min**		4 (0-10)[h]	4 (0-10)[i]	0.123
• **30 min**		5 (0-9)[j]	3 (0-8)[k]	0.656

[a](Appendix VIII: Numeric rating scale for pain), [b]n=99, [c]n=94, [d]n=98, [e]n=88, [f]n= 68, [g]n=8, [h]n=43, [i]n=63? [j]n=20, [k]n=7
*p<0.05 is considered significant
Data are given as median (IQR).
P-values were obtained with the Pearson chi-square test.

3.4.4 Time measures

The duration of the surgery was not significantly different between group A or group B and took 8 (2-21) minutes for group A and 7 (1-27) minutes for group B (p-value=0.183; Table 5). No significant difference was found concerning the pre-operative time, the anaesthesia onset time, and the tourniquet time. The experience of tourniquet discomfort started generally around ten minutes after the tourniquet had been inflated. No difference was detected between both groups (p-value=0.792). Finally, the total time in the operation room was also comparable between group A and B and showed no significant differences (Table 5).

Table 5: ***Secondary outcomes: time measurements.***

Variable	Group A (n =100)	Group B (n=95)	p-value*
Duration of surgery	8 (2-21)	7 (1-27)	0.183
Anaesthesia onset time	5 (5-10)[a]	5 (4-9)[b]	0.922
Pre-operative time	8 (4-22)[c]	8 (2-29)	0.441
Tourniquet tolerance time	10 (5-30)[d]	10 (10-25)[e]	0.792
Tourniquet time	23.50 (11-44)	25 (15-45)	0.066
Total time in the operation room	36 (20-68)[f]	35 (25-56)	0.732

[a]n=75, [b]n=73, [c]n=98, [d]n=51, [e]n=57, [f]n=99
*p<0.05 is considered significant
Data are given in minutes and as median (IQR).
P-values were obtained with the Mann-Whitney U test.

3.5 Results for each type of hand surgery

In this study 71 patients undergoing carpal tunnel surgery were included, together with 58 patients undergoing trigger finger or trigger thumb and 45 patients undergoing dorsal or volar wrist ganglion, this group contained the highest number of patients. The groups of Dupuytren's disease and De Quervain contained a lesser amount of patients, respectively 16 and 5 patients. Data of the primary and secondary outcomes was analysed separately for each type of hand surgery to determine possible significances between group A and group B for each disease. Patient characteristics at baseline are represented in table 6 and showed no significant differences between group A and group B for each type of surgery, with the exception that there were significantly more men undergoing surgery for Dupuytren's disease (p-value=0.021).

The quality of the block was analysed in 4 grades and in 2 grade (complete/incomplete) and showed no significant difference in both cases for any of the conditions (p-value>0.05; Table 7). Seventy five

percent of the patients who underwent surgery for carpal tunnel and were randomized in group A had a complete block. This amounted 65.7 percent for the patients in group B. The majority of the patients who underwent surgery for trigger finger and trigger thumb had a block of grade 2 (partial motor blockade, no pain or deep pressure sensitivity). This was also the case for the patients of Dupuytren's disease. For the patients with a wrist ganglion was found that 84 percent in group A and 95 percent in group B had a complete blockade. For the patients with De Quervain this even amounted to 100 percent for both group A and B.

The quality of the surgical field was not significantly different between group A and group B for all condition types (p-value>0.05). The median score for the two groups for all conditions (except group B of carpal tunnel) was 4 or "a good surgical field" (Data not shown). Again, for patient satisfaction, no significance was found in any of the groups (p-value>0.05). The highest percentages were found for a satisfaction score of "7" in the groups of carpal tunnel, trigger finger or trigger thumb, Dupuytren's disease and wrist ganglions. In the group of De Quervain, the highest percentage was found for a satisfaction score of "6" (Table 7).

NRS-pain scores for each type of hand surgery are outlined in table 8. No significant differences were found for the NRS score prior to the surgery, the NRS-pain score provoked by the placing of the anaesthesia, or the NRS-pain score at first incision (p-value>0.05). The NRS tourniquet pain score was not significant in any of the different conditions (p-value>0.05).

Table 9 represents the time measurements that were assessed during the study. No significant differences in anaesthesia onset time, pre-operative time, tourniquet tolerance time, duration of surgery, and total time in the operation room were found comparing group A and group B in the different types of hand surgery. The outcome "tourniquet time" showed only significance in the patients undergoing surgery for trigger finger or trigger thumb (p-value=0.001).

Table 6. Patient characteristics for each type of hand surgery.

Variable	Carpal tunnel (n=71)			Trigger finger and trigger thumb (n= 58)			Dupuytren's disease (n=16)			Wrist ganglion (n=45)			De Quervain (n=5)		
	Group A (n=36)	**Group B (n=35)**	**p-value***	**Group A (n=29)**	**Group B (n=29)**	**p-value***	**Group A (n=8)**	**Group B (n=8)**	**p-value***	**Group A (n=25)**	**Group B (n=20)**	**p- value***	**Group A (n=2)**	**Group B (n=3)**	**p- value***
Age (years)	64.58 (±15.98)	58.97 (±12.53)	0.105[b]	59.48 (±10.18)	63.90 (±12.93)	0.154[b]	62.38 (±12.17)	63.25 (±5.12)	0.855[b]	43.36 (± 17.49)	42.15 (±16.66)	0.815[b]	40.50 (±14.85)	63.33 (±15.57)	0.201
Gender (male/female)	18/18 (50%/ 50%)	16/19 (45.7%/ 54.3%)	0.718[c]	15/14 (51.7%/ 48.3%)	12/17 (41.4%/ 58.6%)	0.430[c]	4/4 (50%/ 50%)	8/0 (100%/ 0%)	0.021*	8/17 (32%/ 68%)	5/15 (25%/ 75%)	0.607[c]	0/2 (0%/100%)	0/3 (0%/100%)	/
Location of surgery (Right/left)	21/15 (58.3%/ 41.6%)	25/10 (71.4%/ 28.6%)	0.248[c]	14/15 (48.3%/ 51.7%)	15/14 (51.7%/ 48.3%)	0.793[c]	4/4 (50%/ 50%)	3/5 (37.5%/ 62.5%)	0.614[c]	10/15 (40%/ 60%)	13/7 (65%/ 35%)	0.095[c]	2/0 (100%/0%)	1/2 (33%/67%)	0.136

*p<0.05 is considered significant

Data are given as mean (±SDV) or as absolute numbers (percentage of the total subjects).

P-values were obtained with:

[b]Independent sample t test

[c]Pearson chi square

Table 7. Study outcomes for each type of hand surgery.

Variable		Carpal tunnel (n=71)			Trigger finger and trigger thumb (n =58)			Dupuytren's disease (n=16)		
		Group A (n=36)	**Group B (n=35)**	**p- value***	**Group A (n=29)**	**Group B (n=29)**	**p- value***	**Group A (n=8)**	**Group B (n=8)**	**p- value***
Quality of the block	Grade1 [a]	16 (44.4%)	14 (40%)	0.688	2 (6.9%)	3 (10.3%)	0.149	0 (0%)	0 (0%)	0.590
	Grade 2 [a]	11 (30.6%)	9 (25.7%)		18 (62.1%)	23 (79.3%)		6 (75%)	5 (62.5%)	
	Grade 3 [a]	9 (25%)	12 (34.3%)		9 (31%)	3 (10.3%)		2 (25%)	3 (37.5%)	
	Grade 4[a]	0 (0%)	0 (0%)		0 (0%)	0 (0%)		0 (0%)	0 (0%)	
	Complete/ incomplete[b]	27/9 (75%/25%)	23/12 (65.7%/34.3%)	0.391	20/9 (69%/31%)	26/3 (89.7%/10.3%)	0.052	6/2 (75%/25%)	5/3 (62.5%/37.5%)	0.590
Quality of the surgical field	Unacceptable	1 (2.8%)	0 (0%)	0.521	1 (3.4%)	0 (0%)	0.679	0 (0%)	0 (0%)	0.352
	Bad	1 (2.8%)	0 (0%)		0 (0%)	0 (0%)		0 (0%)	1 (12.5%)	
	Moderate	2 (5.6%)	3 (8.6%)		4 (13.8%)	5 (17.2%)		0 (0%)	0 (0%)	
	Good	15 (41.7%)	11 (31.4%)		18 (62.1%)	16 (55.2%)		5 (62.5%)	6 (75%)	
	Excellent	17 (47.2%)	21 (60%)		6 (20.7%)	8 (27.6%)		3 (37.5%)	1 (12.5%)	
Patient satisfaction	1 [c]	0 (0%)	1 (2.9%)	0.588	0 (0%)	1 (3.4%)	0.312	0 (0%)	0 (0%)	0.543
	2 [c]	0 (0%)	0 (0%)		0 (0%)	1 (3.4%)		0 (0%)	0 (0%)	
	3 [c]	0 (0%)	2 (5.7%)		2 (6.9%)	1 (3.4%)		1 (12.5%)	0 (0%)	
	4 [c]	2 (5.6%)	2 (5.7%)		4 (13.8%)	0 (0%)		0 (0%)	0 (0%)	
	5 [c]	8 (22.2%)	5 (14.3%)		2 (6.9%)	3 (10.3%)		2 (25%)	1 (12.5%)	
	6 [c]	8 (22.2%)	7 (20%)		7 (24.1%)	10 (34.4%)		2 (25%)	3 (37.5%)	
	7[c]	16 (44.4 %)	15 (42.9%)		14 (48.3%)	13 (44.8%)		2 (25%)	4 (50%)	
	Missing values	2 (5.6%)	3 (8.6%)		0 (0%)	0 (0%)		1 (12.5%)	0 (0%)	

[a](grade 1: complete motor and sensory block; grade 2: partial motor blockade, no pain or deep pressure sensitivity; grade 3; partial motor blockade, mild pain with need for local or opioid rescue medication; grade 4: incomplete motor and sensory blockade with the need for sedation or conversion to GA)
[b](Complete = grade 1 + grade 2, incomplete = grade 3 + grade 4)
[c]Seven point Likert scale (0 = extremely dissatisfied and 7 = extremely satisfied)
*p<0.05 is considered significant
Data are given as median (IQR) or as absolute numbers (percentage of the total subjects).
P-values were obtained with the Pearson Chi-Square test.

Table 7: continued

Variable		Wrist ganglion (n=45)			De Quervain (n =5)		
		Group A (n=25)	**Group B (n=20)**	**p- value***	**Group A (n=2)**	**Group B (n=3)**	**p- value***
Quality of the block	Grade 1 [a]	4 (16%)	1 (5%)	0.346	1 (50%)	1 (33.3%)	0.709
	Grade 2 [a]	17 (68%)	18 (90%)		1 (50%)	2 (66.7%)	
	Grade 3 [a]	3 (12%)	1 (5%)		0 (0%)	0 (0%)	
	Grade 4[a]	1 (4%)	0 (0%)		0 (0%)	0 (0%)	
	Complete/ incomplete[b]	21/4 (84%/16%)	19/1 (95%/5%)	0.243	2/0 (100%/0%)	3/0 (100%/0%)	/
Quality of the surgical field	Unacceptable	0 (0%)	0 (0%)	0.064	0 (0%)	0 (0%)	0.709
	Bad	0 (0%)	0 (0%)		0 (0%)	0 (0%)	
	Moderate	1 (4%)	5 (25%)		0 (0%)	0 (0%)	
	Good	15 (60%)	12 (60%)		1 (50%)	2 (66.7%)	
	Excellent	9 (36%)	3 (15%)		1 (50%)	1 (33.3%)	
Patient satisfaction	1[c]	1 (4%)	0 (0%)	0.549	0 (0%)	0 (0%)	0.329
	2 [c]	0 (0%)	1 (5%)		0 (0%)	0 (0%)	
	3 [c]	1 (4%)	2 (10%)		0 (0%)	0 (0%)	
	4 [c]	2 (8%)	0 (0%)		0 (0%)	1 (33.3%)	
	5 [c]	4 (16%)	2 (10%)		0 (0%)	0 (0%)	
	6 [c]	5 (20%)	6 (30%)		1 (50%)	2 (66.7%)	
	7 [c]	9 (36%)	8 (40%)		1 (50%)	0 (0%)	
	Missing values	3 (12%)	1 (5%)		0 (0%)	0 (0%)	

[a](grade 1: complete motor and sensory block; grade 2: partial motor blockade, no pain or deep pressure sensitivity; grade 3; partial motor blockade, mild pain with need for local or opioid rescue medication; grade 4: incomplete motor and sensory blockade with the need for sedation or conversion to GA)
[b](Complete = grade 1 + grade 2, incomplete = grade 3 + grade 4)
[c]Seven point Likert scale (0 = extremely dissatisfied and 7 = extremely satisfied)
*p<0.05 is considered significant
Data are given as median (IQR) or as absolute numbers (percentage of the total subjects).
P-values were obtained with the Pearson Chi-Square test.

Table 8: NRS pain scores for each type of hand surgery

Variable		Carpal tunnel (n=71)			Trigger finger and trigger thumb (n=58)			Dupuytren's disease (n=16)		
		Group A (n=36)	**Group B (n=35)**	**p- value***	**Group A (n=29)**	**Group B (n=29)**	**p- value***	**Group A (n=8)**	**Group B (n=8)**	**p- value***
NRS pain score at baseline	0-10[a]	0 (0-8)	0 (0-7)	0.167	0 (0-6)	1 (0-7)	0.705	0 (0-5)	0 (0-6)	0.549
NRS pain score at time of placement anaesthetic blockade	0-10[a]	3 (0-8)	3 (0-9)	0.978	4 (0-10)	2 (0-8)[h]	0.064	3 (0-7)	3 (1-7)	0.544
NRS pain score at first incision	0-10[a]	0 (0-7)	2 (0-8)	0.134	2 (0-8)	0 (0-8)	0.582	1 (0-6)	1 (0-10)	0.308
NRS tourniquet pain score at:	0-10[a]									
• **10 minutes**		2 (0-7)	3 (0-10)	0.065	0 (0-8)	3 (0-8)	0.288	2.5 (0-6)	4 (1-9)	0.780
• **15 minutes**		3 (0-8)	3 (0-10)	0.375	2 (0-8)[i]	3 (0-10)	0.751	2.5 (0-7)	4.5 (2-9)	0.701
• **20 minutes**		3 (0-9)[b]	3 (0-10)[c]	0.287	4 (0-7)[j]	4 (0-10)[h]	0.899	4 (1-7)	6 (2-8)[g]	0.586
• **25 minutes**		4 (0-8)[d]	4 (0-10)[e]	0.442	5 (0-8)[k]	5 (0-9)[l]	0.553	2 (2-7)[m]	4.5 (2-7)[o]	0.709
• **30 minutes**		5 (2-8)[f]	3 (0-8)[g]	0.494	5 (0-6)[m]	/[n]	0.261	1.5 (0-3)[o]	/[n]	0.223

[a](Appendix VIII: Numeric rating scale for pain), [b]n=30, [c]n=33, [d]n=23, [e]n=27, [f]n=12, [g]n=5, [h]n=28, [i]n=24, [j]n=16, [k]n=8, [l]n=19, [m]n=3, [n]n=1, [o]n=2
*p<0.05 is considered significant
Data are given as median (IQR).
P-values were obtained with the Pearson chi-square test

Table 8: continued

Variable		Wrist ganglion (n=45)			De Quervain (n=5)		
		Group A (n=25)	**Group B (n=20)**	**p- value***	**Group A (n=2)**	**Group B (n=3)**	**p- value***
NRS pain score prior to placement anaesthetic blockade	0-10[a]	3 (0-8)	0 (0-8)[b]	0.508	3 (2-4)	5 (3-5)	0.172
NRS pain score at time of placement anaesthetic blockade	0-10[a]	6 (0-10)	4 (0-7)	0.128	7 (7-7)	4 (0-5)	0.172
NRS pain score at first incision	0-10[a]	0 (0-6)[b]	0 (0-4)	0.421	0 (0-0)	0 (0-0)	0.172
NRS tourniquet pain score at:	0-10[a]						
• **10 minutes**		2 (0-10)[c]	2.5 (0-8)	0.346	0 (0-0)	4 (2-9)	0.172
• **15 minutes**		2.5 (0-10)[d]	2.5 (0-9)	0.303	1 (0-2)	6 (2-9)	0.405
• **20 minutes**		3.5 (0-10)[e]	4 (0-9)[d]	0.318	2.5 (2-3)	6 (3-9)	0.405
• **25 minutes**		5 (0-10)[f]	4 (0-10)[g]	0.726	/[i]	/[i]	0.157
• **30 minutes**		7 (4-9)[h]	/	/	/[j]	/[j]	/

[a](Appendix VIII: Numeric rating scale for pain), [b]n=24, [c]n=23, [d]n=18, [e]n=12, [f]n=8, [g]n=14, [h]n=3, [i]n=1, [j]n=0
*p<0.05 is considered significant
Data are given as median (IQR)
P-values were obtained with the Pearson chi-square test.

Table 9: Time measurements for each type of hand surgery

Variable	Carpal tunnel (n=71)			Trigger finger and trigger thumb (n=58)			Dupuytren's disease (n=16)			Wrist ganglion (n=45)			De Quervain (n=5)		
	Group A (n=36)	**Group B (n=35)**	**p- value***	**Group A (n=29)**	**Group B (n=29)**	**p-value***	**Group A (n=8)**	**Group B (n=8)**	**p-value***	**Group A (n=25)**	**Group B (n=20)**	**p-value***	**Group A (n=2)**	**Group B (n=3)**	**p-value***
Anaesthesia onset time	5 (5-7)[a]	5 (5-8)[b]	0.103[n]	6 (5-10)[e]	5 (5-9)[b]	0.343[n]	5 (5-8)[i]	5 (5-7)[i]	0.906[n]	5 (5-10)[j]	5 (4-9)	0.286[n]	5 (±0.00)	5.50 (±0.71)[m]	/
Pre-operative time	9 (5-22)	9 (3-29)	0.473[n]	8 (4-18)[f]	9 (2-22)	0.885[n]	6 (4-19)	7 (4-10)	0.957[n]	7 (4-19)[k]	7 (5-18)	0.748[n]	10.50 (±2.12)	13.33 (±8.08)	0.675[o]
Tourniquet tolerance time	10 (5-25)[c]	10 (10-25)[d]	0.428[n]	10 (10-25)[g]	10 (10-20)[h]	0.232[n]	15.00 (±5.00)[i]	13.20 (±2.39)[i]	0.488[o]	10 (10-30)[l]	10 (10-20)[l]	0.890[n]	/	10 (10-25)	/
Tourniquet time	27.72 (±5.87)	26.11 (±3.60)	0.167[o]	20 (11-36)	25 (15-34)	0.001*	23 (20-34)	25.50 (20-45)	0.524[n]	20 (13-32)	25 (18-29)	0.033[n]	24.50 (23-26)	24 (24-25)	1.00[n]
Duration of surgery	11.00 (±4.00)	9.00 (±3.00)	0.086[o]	6 (2-20)	5 (1-18)	0.397[n]	12 (±5)	14 (±6)	0.475[o]	7 (4-18)	7 (4-17)	0.963[n]	10 (±1)	7 (±2)	0.123[o]
Total time in the operation room	41.00 (±9.00)	38.00 (±6.00)	0.180[o]	29 (20-53)	35 (25-49)	0.038[n]	35 (28-48)	33 (30-56)	0.791[n]	32 (±7)[k]	34 (±5)	0.390[n]	41 (±0.00)	39 (±7)	0.792[n]

*p<0.05 is considered significant

[a]n=26, [b]n=23, [c]n=19, [d]n=21, [e]n=20, [f]n=28, [g]n=15, [h]n=16, [i]n=5, [j]n=22, [k]n=24, [l]n=12, [m]n=2

Data are presented in minutes and as median (IQR) or as mean (±SDV). P-values were obtained with the Mann-Whitney U[n] test and the Independent samples [o]T-test.

4. DISCUSSION

The use of the IVRA technique or Bier block for surgery on the upper limb is well recognized. It was developed in 1908 by August Bier and became a popular technique to obtain (regional) anaesthesia for limb surgery [10]. However, the Bier block comprises the potential risk of LAST symptoms due to for example accidental loosening of the tourniquet [19]. In addition, the tourniquet system can elicit ischemic pain and irritation [8, 21]. Traditionally, the placement of a tourniquet on the forearm was not used, because it was assumed that a forearm tourniquet cannot block the arteries situated between the radius and the ulna [35], resulting in insufficient hemostasis and leakage of the LA into the circulation [19, 24]. Nevertheless, this theory has never been demonstrated in any study [10]. Additionally, several studies that assessed the safety and efficacy of the forearm tourniquet suggest it to be a safer method than the regular Bier block, because of a lower, nontoxic dosage of LA that is required for the mini-Bier block [19, 24]. Finally, according to several authors who performed research concerning the use of the forearm tourniquet, ischemic tourniquet pain is reduced and consequently the operative time will be decreased [36, 37]. Currently, there are only a few studies that performed a direct comparison between the conventional Bier block and the mini-Bier block. Moreover, these studies included only a small number of patients. Therefore, the aim of this prospective study was to investigate non-inferiority between the conventional Bier block and the mini-Bier block in a large population undergoing hand surgery, which also makes this study unique.

Results of the data analyses showed that the mini-Bier block is non-inferior compared to the Bier block in an adult population undergoing ambulatory surgery for carpal tunnel, trigger finger and/or trigger thumb, Dupuytren's disease, dorsal and volar wrist ganglions, and De Quervain.

4.1 Primary outcome: Quality of the block

Investigation of the quality of the block during the operation shows that there is no significant difference between group A and group B, which suggests that both methods are equally effective in obtaining an effective loss of sense in the region of the hand were surgery was performed. This also implies indirectly that no significance was obtained for the need for supplementary analgesia or conversion to sedation or GA during the surgery. When a complete versus an incomplete block in both groups was compared, we could conclude that 76% of the patients in group A and 80% of the patients in group B obtained a complete block. This is does not correspond to the percentage that was expected to be obtained based on a previous meta-analysis [19]: a complete block of 98.5% for the mini-Bier block and 100% for the conventional Bier block. The grade that was scored the most in both groups

was grade 2 (partial motor blockade, no pain or deep pressure sensitivity). So despite the reduced dose of LA that was administered in the group of the forearm IVRA, this is as effective in providing a sensory block compared to the conventional IVRA. This also implies that the potential leakage of LA into the circulation does not occur more in the mini-Bier block compared to the regular Bier-block. This was also shown in a cross-over study by Coleman et al. [38], who looked at the occurrence of a leakage of a radiolabeled element with a structure that was similar to lidocaine in both the mini-Bier block and the conventional Bier method. A similarity of radiolabeled substance leakage was found in both groups when inflation of the tourniquet was performed. Contrary, when deflation happened, more radioactivity was noticed in the group of the upper arm tourniquet (p-value<0.001), which was caused because of the higher dose that they received. The conclusion of this study was that both groups are comparable in terms of tourniquet leakage and, more important, the mini-Bier block is potentially safer because of the smaller dose of LA. Finally, the explanation for the high rate of incomplete blocks (most frequently grade 3, pain and need for rescue medication) might be the result of starting the surgery to fast after injection of the LA. No distinction was made when exactly the rescue medication was administered (right after the first incision or already during the surgery). Moreover, Horn et al. found a delayed spread of the LA from the site of injection (which is the dorsum of the hand) to the palm of the hand. Based on these findings, surgeons who perform hand surgery with the use of an IVRA method should postpone an early start of the operation if the location of the surgery is on the palm of the hand. This is opposing to the location of the surgery on the dorsal side of the hand, where a sensory block will be reached much faster.

4.2 Secondary outcomes

4.2.1 Quality of the surgical field

One of our secondary outcome measures was the quality of the surgical field. Overall, the quality of the surgical field was equally as good in both groups of anesthesia, with only two cases where the absence of blood in the surgical field was assessed as “bad” and only one person in group A had an unacceptable field. However, the randomized clinical trial of Frank et al. (2009) proved that the mini-Bier block is associated with a drier surgical field and less oozing than the conventional Bier block.

4.2.2 Patient satisfaction

Patients indicated high scores of satisfaction 24 hours after the surgery concerning the type of anaesthesia that was used, with a median score of six (satisfied) for both groups on the seven point Likert scale. Overall, patients did not seem to be more or less satisfied of the forearm IVRA in comparison with the upper arm IVRA, as no significant difference was obtained.

4.2.3 NRS-pain scores

The NRS-pain scores at baseline, during the placement of the anaesthetic blockade and at the time when the first incision is made were not significantly different. However, a trend might be noticed for the NRS score at first incision. Patients of group A had a median score of 1 at baseline, while this was 0 for group B. The injection of the local anaesthetic seemed to elicit a higher median NRS pain-score for both the forearm and upper arm IVRA (4 for group A and 3 for group B). Finally, the sensory block at the time of the first incision was comparable in both techniques, as the median NRS pain-score was 0 or "no pain". However, when these three moments of NRS pain-scores were looked at as repeated measurements, a significant difference could be noticed between group A and B. A trend of a higher NRS-pain score at the time of the placement of the block in group A can be noticed, while the NRS-pain scores at baseline and at the start of the surgery show comparable for both groups. Finally, the NRS tourniquet pain score was assessed 10, 15, 20, 25, and 30 minutes after inflation. The results indicate that the two techniques did not differ with respect to the placement of the tourniquet on either the forearm or the upper arm. On overall, the median score of group A seems to increase from a median score of 2 after 10 minutes to a median score of 5 at 30 minutes. This was as expected, because as time of inflation takes longer, patients would complain more of irritation, discomfort and an ischemic pain. In group B this NRS tourniquet pain-score remained rather constant, with a median score of 3 after 10 minutes to a somewhat higher score of 4 at 20 and 25 minutes, to finally again a lower median score after 30 minutes of inflation. This might be explained by the fact that, as was not expected, a lot of patients tend to get used to the inflated tourniquet as time progresses. However, in literature, the forearm tourniquet was tolerated a longer period of time in comparison with the upper arm tourniquet [25, 39]. For example, in the study of Hutchinson and McClinton (1994) it was noticed that the forearm tourniquet was tolerated approximately 45% longer than the upper arm tourniquet and also was less painful. Chiao et al. (2013) reported that patients who had the tourniquet placed on the forearm experienced less tourniquet pain than the patients of the conventional Bier block. They suggested that this enhanced toleration of the forearm tourniquet could be explained by the anatomical differences between the forearm and the upper arm. They speculated that the radius and the ulnar bones create a "double pillar", which would then reduce the ischemia in the muscles, because pressure could be dissipated more evenly in comparison with the upper arm tourniquet, of which the pressure could only have been absorbed by humerus. Another possibility is the increased density of the LA in the forearm in comparison with the upper arm, which would have contributed to the more bearable pain in the mini-Bier block [39].

4.2.4 Time measurements

Another secondary outcome of this study was the several time measurements before and during surgery. Yet, no significant differences were noticed in any of the time parameters (anaesthesia onset time, pre-operative time, tourniquet tolerance time, tourniquet time, duration of surgery, total time in the operation room). The duration of the surgery had a median of eight minutes for patients in group A and a median time of seven minutes for patients in group B. In addition, the total time that patients spend in the operation room was equally comparable in both groups (36 minutes versus 35 minutes). Therefore, we could conclude none of both anaesthesia techniques had a direct influence on these durations. Moreover, the pre-operative time was the same in both methods that were used to obtain analgesia. This could be expected, since pre-operative time is rather influenced by other factors, such the time for the surgeon to enter the operation room, the speed of preparation of the patient, etc. The tourniquet tolerance time had for both groups a median of 10 minutes. However, as previously stated, several studies reported a significantly better tolerance for the patients of the group of the mini-Bier block in comparison with the patients of the upper arm IVRA. Yet, in our study this tourniquet toleration time was not significant different between both groups, which implicates that the use of a forearm tourniquet does not necessarily requires less time in the operation room. Finally, no significant difference was found in the onset time of the anaesthetic block, whether 40 ml of lidocaine or 25 ml of lidocaine was administered. Both groups seemed to have obtained a sensory block five minutes after injection of the LA. This is comparable to the study of Singh et al. (2009), who reported a comparable onset of sensory blockade in their two study groups of upper arm IVRA using 0.5% lidocaine at a dose of 3 mg/kg with ketorolac 0.3 mg/kg and a forearm IVRA with 0.5% lidocaine of 1.5 mg/kg with ketorolac at 0.15 mg/kg [24]. Peng et al. (2002) did an investigation on a different type of LA, but found that onset time of anaesthesia and motor block were similar in both treatment groups (forearm IVRA with 0.4 ml/kg of ropivacaine 0.375% or forearm IVRA with 0.4 ml/kg of lidocaine 0.5%), which suggest that the type of the injected LA has also no significant difference in time passed to obtain a sensory block [40].

4.3 Limitations

This comparative study had some limitations. The first limitation is that this study is still ongoing (82 patients still need to be included). Therefore, the study could not be unblinded to perform the data analysis. So at the present, no definitive conclusions could have been drawn yet. The second limitation was the difficulty to maintain blinding. We did this to avoid influence of the researcher or the surgeon on the answers of the outcomes of this study on the NRS-pain scores, the satisfaction concerning the grading of the block and the quality of the surgical field, and the satisfaction of the patient. Yet, in

some cases it was not possible to keep the blinding because patients would reveal accidently where they felt the pressure of the tourniquet, or a second (un-inflated) tourniquet was forgotten to have been applied on the required place of the arm. Third limitation involved the determination of the onset time of the block. The study protocol states that the pin prick test should be carried out 5 minutes after injection of the LA. However, in some cases this was not possible since the nurses or surgeon would be already busy with disinfecting and establishing a sterile working environment. In those cases the first pin prick testing would only be possible after for example six, seven, or even eight minutes. Those cases were consequently marked as missing values. Finally, the fourth limit of this study was the difficulty or obtaining the profit of around ten minutes when the patient would have had the anaesthetic method of mini-Bier block. For example, if the surgery would be finished when the tourniquet time would be 15 minutes, the choice was either to directly deflate the tourniquet and gain ten minutes (as the study protocol states that the upper arm IVRA should only be deflated after 25 minutes) or leave the tourniquet inflated for another ten minutes in order to keep the blind for the researcher. In our study the choice was made to keep the blinding of the researcher. However, this could possibly have let to the insignificance of the outcome “tourniquet time” between both group A and B.

5. CONCLUSION

The primary goal of this study was to investigate whether the upper arm Bier block with 0.5% lidocaine at a dose of 40 ml is non-inferior to the forearm mini-Bier block with 0.5% lidocaine at a dose of 25 ml in patients undergoing hand surgery. Our prospective, randomized, controlled, researcher-blinded study showed that the mini-Bier block is non-inferior to the regular Bier block for the quality of the block and the quality of the surgical field. Twenty four hours after surgery, there were no significant differences seen in the patient satisfaction of both groups. Moreover, the NRS-pain scores at baseline, at time of placement of the anesthetic block and at the start of the surgery are comparable. The NRS-tourniquet pain scores showed no significance, which implies that placement of the tourniquet is equally painful on the upper arm as on the forearm. Time measurements proved that the onset time of the block is the same for both the forearm as the upper arm IVRA. Furthermore, the tourniquet tolerance time and tourniquet time were found to be similar for both methods. The duration of the surgery and the total time the patient spent in the operation room was not significantly influenced by neither the mini-Bier block nor the regular Bier block. We can conclude that the mini-Bier block is equally effective in providing RA using a lower dosage of anaesthetic as the conventional Bier block. Future studies can elaborate on optimizing the safest and most efficient combination of type and dosage of LA in order to obtain the best possible analgesia for upper limb surgeries

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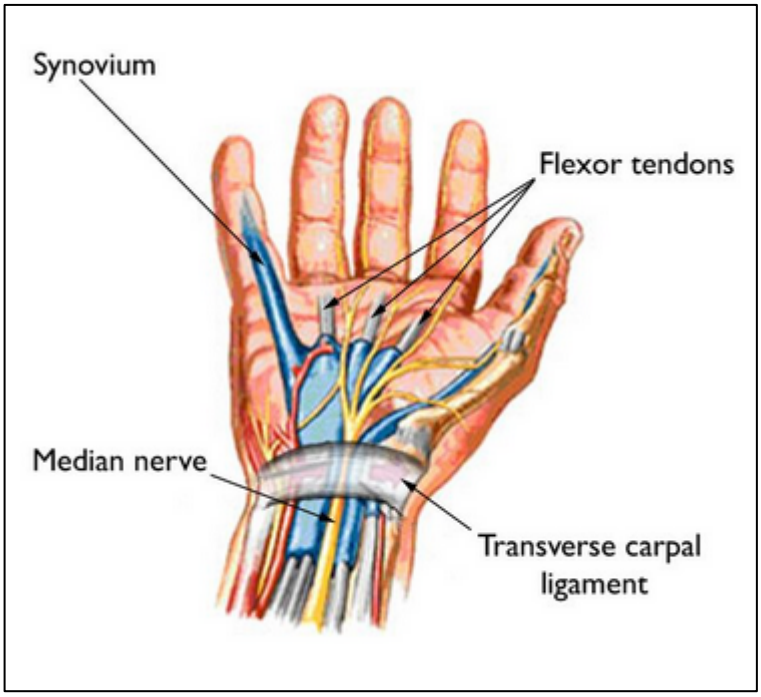
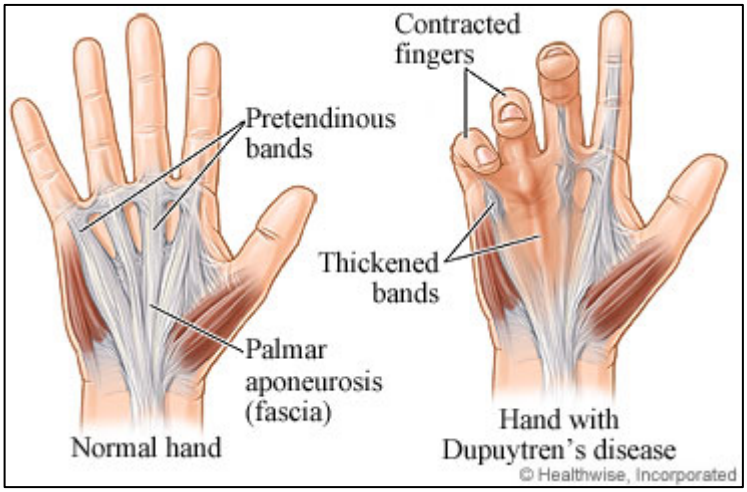
7. APPENDIX

Appendix I) Carpal tunnel syndrome



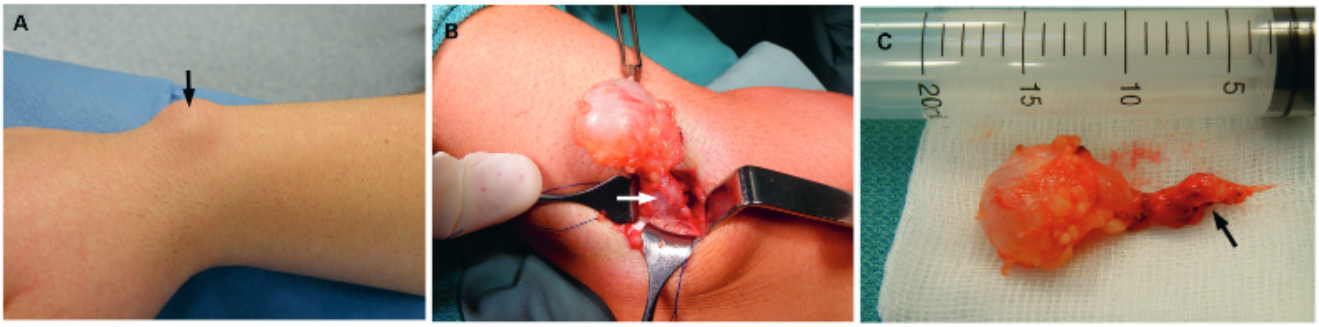
Carpal tunnel syndrome *is caused by the pressure on the median nerve, which runs through the carpal tunnel. This canal also encloses the bones of the wrist, the transverse carpal ligament, and the digital flexor tendons [27, 42].*

Appendix II) Dupuytren's disease

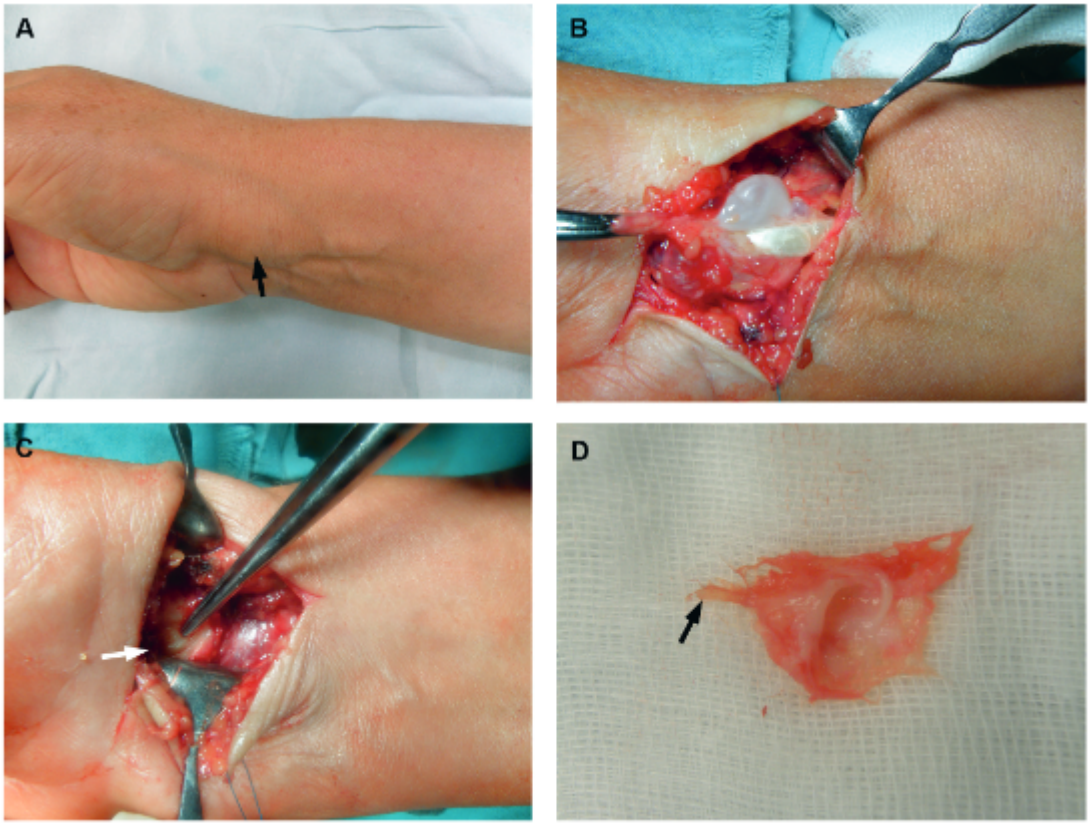


Dupuytren's disease is fibro-proliferative disorder of the palmar and digital fascia of the hand. This disease is characterized by fibrous collagenous cords that extend into the fingers. The progression of this disorder is variable and defined by the maturation, thickening, and contraction of these cords, which causes permanent flexion deformities of the digits [28, 43].

Appendix III) Dorsal and volar wrist ganglions

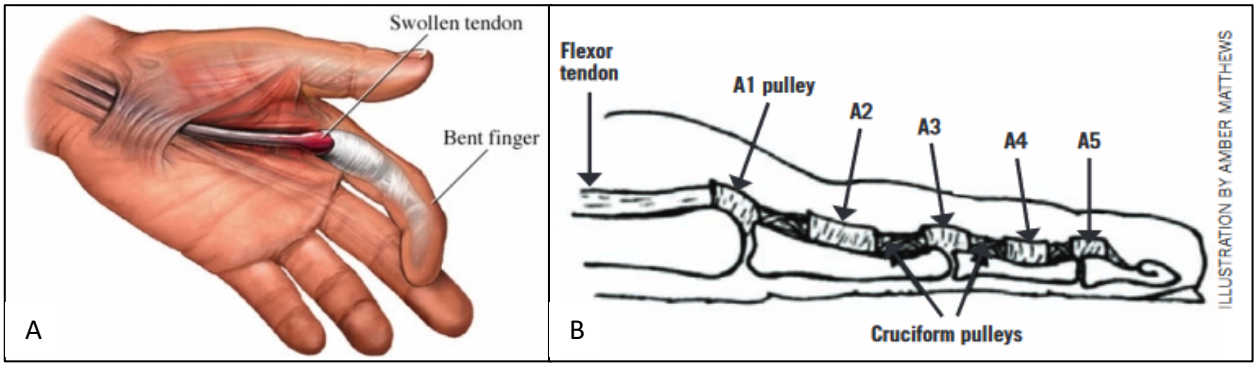


Dorsal wrist ganglion. A. Clinical presentation of a dorsal wrist ganglion (black arrow); **B.** Per-operative view: release of the ganglion cyst together with the duct (white arrow); **C.** Post-operative view: the ganglion cyst together with the duct (black arrow) after surgey [30].



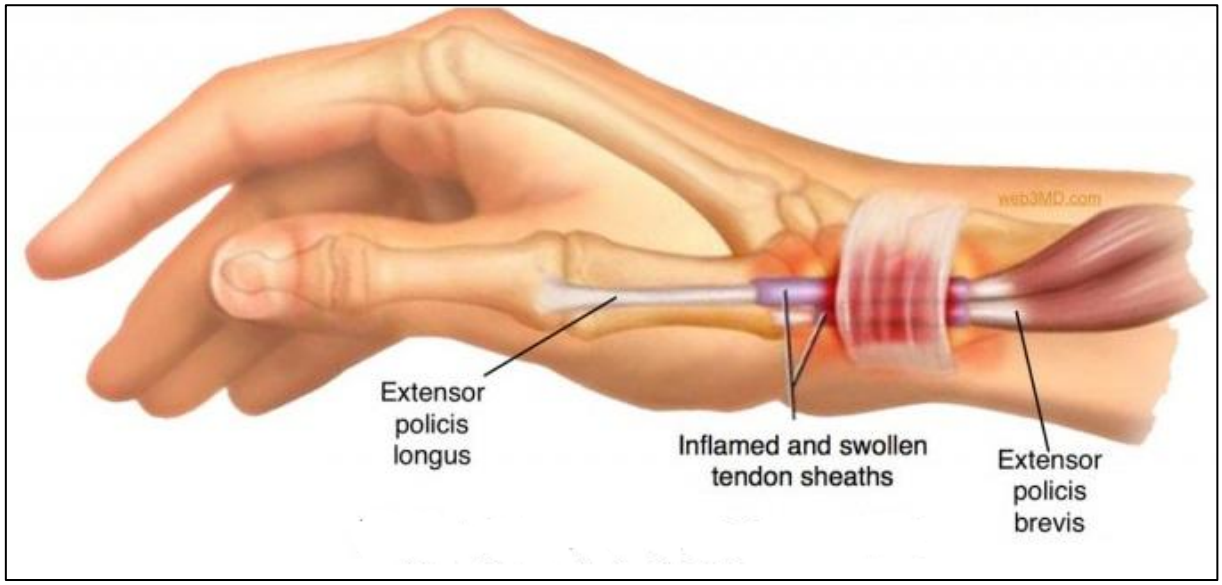
Volar wrist ganglion. A. Clinical presentation of a volar wrist ganglion situated at the radial area of the wrist (black arrow); **B.** Per-operative view: release of the volar ganglion cyst; **C.** Per-operative view: the place of connection of the stalk of the cyst with the radiocarpal joint (white arrow); **D.** Post-operative view: presentation of theganglion cyst together with the duct (black arrow) after surgery [30].

Appendix IV) Trigger finger



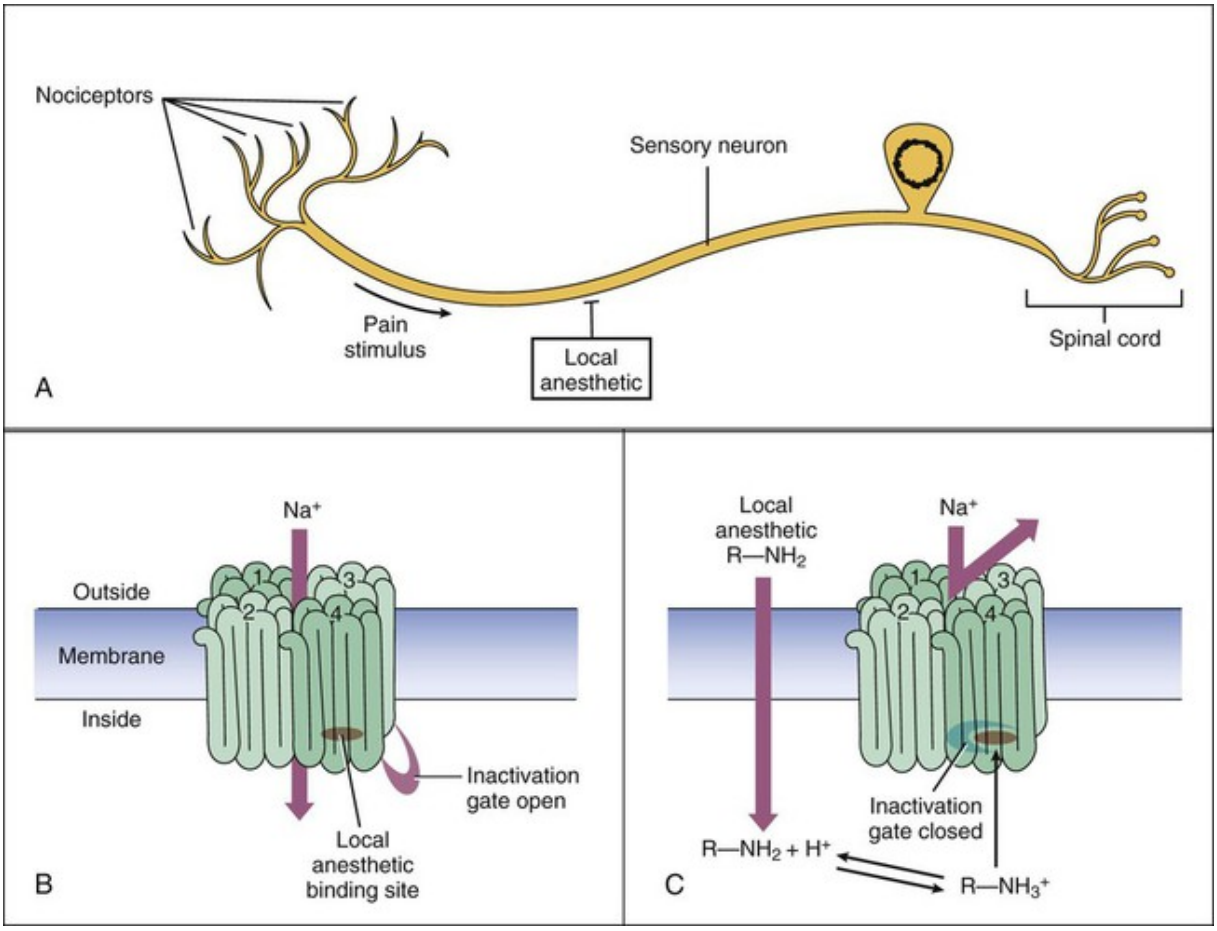
Trigger finger. A. Trigger finger in the second digit. Tendon hypertrophy and sheath limitation appears. This hinders the smooth sliding of the tendon through the sheat, causing the sensation of a “caught” or “locked” finger. **B. Lateral view of the fourth digit.** The flexor tendon runs through several sheats: the annular and cruciform pulleys. These sheats encapsulate the tendon to keep it attached to the bone in the flexed form of the finger [31, 44].

Appendix V) De quervain tenosynovitis



De quervain Tenosynovitis. This disease affects the abductor pollicis longus (APL) and the extensor pollicis brevis (EPB) tendons, running trough the wrist. Repetitive and continued pressure of the APL and EPB tendons cause symptoms of pain and inflammation [33, 45].

Appendix VI) Mechanism of action of local anaesthetics

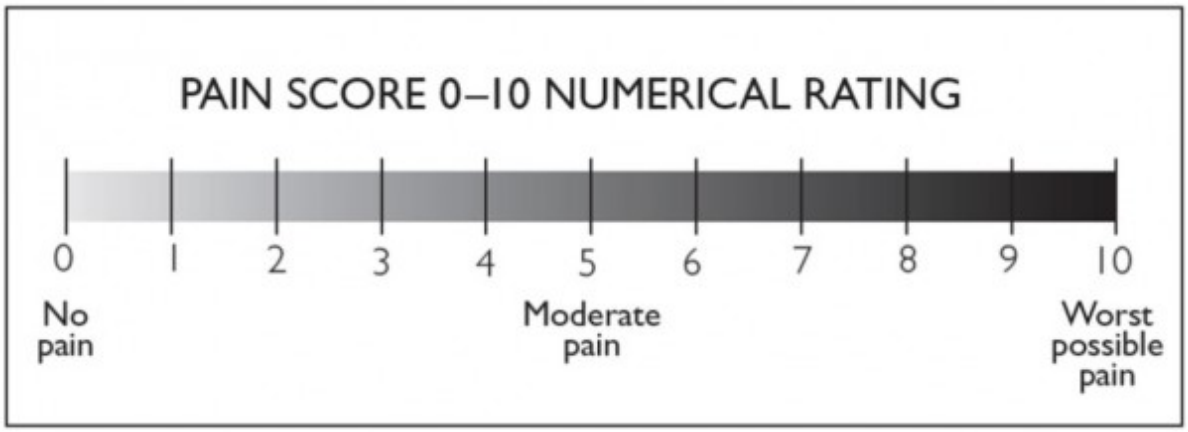


Mechanisms of action of local anesthetics. A. The local anesthetic (LA) binds to sodium channels of the sensory neuron and stops the generation and conduction of action potentials. **B.** The sodium channel includes four large transmembrane domains. The LA binds to amino acid residues located on domain 4. **C.** The uncharged form of the local anesthetic ($R—NH_2$) diffuses through the neural sheats into the axoplasm and is then converted to the ionized form ($R—NH_3^+$). The ionized form attaches to the sodium channel in the open state, and this results in the sodium channel inactivation status. Sodium entry is blocked during the inactivation state. Nerve depolarization is consequently prevented [34, 46].

Appendix VII) American Society of Anesthesiologists physical status classification

ASA Physical status classification	
Class	**Definition**
I	A normal healty patient
II	A patient with a mild, systemic disease
III	A patient with a severe systemic disease that is not life-threatening.
IV	A patient with a severe systemic disease that is a constant threat to life.
V	A moribund patient who is not expected to survive beyond the next 24 hours without the operation.
VI	A brain-dead patient whose organs are being removed with the intention of transplanting them into another patient.
E	The addition of “E” to the ASAPS denotes an emergency surgical procedure.
The American Society of Anaesthesiologists physical status system is used by clinicians to assess the physiological status of patients to predict the operative risk. ASA: American Society of Anesthesiologists; ASAPS: American Society of Anesthesiologists physical status [41].	

Appendix VIII) Numeric rating scale for pain



The numerical rating scale (NRS) for pain. This scale is presented to the patients. The NRS-pain score is a number between zero and ten, with zero is no pain and ten is the worst imagineable pain. Patients have to indicate which number corresponds to the pain they are feeling at the time of questioning.