Best Practice & Research Clinical Anaesthesiology 28 (2014) 29–39

Contents lists available at ScienceDirect

Best Practice & Research Clinical Anaesthesiology

journal homepage: www.elsevier.com/locate/bean

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Ultrasound and its evolution in perioperative regional anesthesia and analgesia

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Keywords:
perioperative analgesia
pain management
ultrasound
local anesthetics
regional anesthesia

Perioperative regional anesthetic and analgesic techniques have evolved considerably over the past four decades. Perhaps, the most impressive development in recent years has been the rapid adoption and widespread utilization of ultrasound (US) guidance to perform targeted delivery of local anesthetics and catheters in a consistent manner for postoperative pain control. This article briefly reviews the history of US in regional anesthesia and perioperative analgesia, the evidence basis for this practice, the clinical application of novel techniques and imaging modalities, and possible future technology and research directions.

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http://dx.doi.org/10.1016/j.bpa.2013.11.001
1521-6896/Published by Elsevier Ltd.

Introduction

Perioperative analgesia is best accomplished by simultaneously attacking multiple targets using a combination of local and systemic medications and techniques (i.e., "multimodal analgesia") [1]. A vital element to any effective multimodal regimen is local or regional anesthesia, although the majority of published multimodal analgesic regimens incorporating regional anesthesia techniques have primarily focused on extremity surgery and joint replacement surgery in particular [2,3]. The art of regional anesthesia lies in the anesthesiologist's ability to accurately and precisely deliver a desired dose of local anesthetic in close proximity to a target nerve and selectively anesthetize a specific part of the body. Mastery of these techniques has always required a keen knowledge and understanding of functional nerve anatomy. Historically, anesthesiologists performing peripheral nerve blockade (PNB) would infer the location of a target nerve or plexus solely based on the identification of relevant surface landmarks with their patients properly positioned; he or she would then direct a needle blindly toward the target, advancing until the desired paresthesia was elicited [4,5]. Inconsistencies in performance or results using these techniques or the lack of training likely limited their universal application even after the advent of electrical stimulation for nerve localization [6].

With the introduction of ultrasound (US) into regional anesthesia practice, there has been renewed and widespread interest in these techniques. Bedside US allows the regional anesthesiologist to visualize nerve and plexus targets directly, study the anatomy of the individual patient, and specifically apply therapeutic injections and catheter placements to be used for surgical anesthesia and perioperative analgesia. Although the reported benefits of US have included decreases in block-related complications and some improvements in certain aspects of block quality, many questions remain regarding the effects, if any, of US-guided regional anesthesia and analgesia (UGRA) on longer-term patient outcomes.

History of US in regional anesthesia

US Doppler technology was used to assist needle insertion for PNB as early as the 1970s [7]. In 1978, La Grange and colleagues published a case series describing a supraclavicular block technique utilizing Doppler localization of the subclavian artery; they reported a 98% success rate in 60 patients and the avoidance of phrenic nerve palsy, pneumothorax, spinal anesthesia, and recurrent laryngeal nerve block [7]. However, the use of US *guidance* in the practice of regional anesthesia arguably began in the late 1980s after Ting and colleagues reported the direct visualization of local anesthetic spreading using B-mode ultrasonography during the performance of an axillary block [8].

Several studies published in the 1990s and early 2000s introduced the possibility of US becoming a nerve localization technique to rival the well-established landmark-based approaches. In 1994, Kapral and colleagues published their widely cited study comparing US-guided supraclavicular block with US-guided axillary block, both in conjunction with nerve stimulation [9]. All blocks were performed with 0.5% bupivacaine mixed with a radiopaque dye in order to confirm the spread of the injectate within the brachial plexus sheath by radiography; the subjects who underwent the supraclavicular block experienced a higher rate of complete sensory anesthesia compared to the subjects who underwent the axillary block, and there were no procedure-related complications [9]. From the same group of investigators, Marhofer and colleagues performed a randomized clinical study comparing the effectiveness of US guidance alone with nerve stimulation for femoral "3-in-1" blocks; US guidance was associated with faster onset of sensory anesthesia, higher block quality, and zero vascular punctures compared to three of 20 in the nerve stimulation group [10]. These studies employed a 7.5-MHz linear array transducer and a 24-gauge needle [9,10]. The investigators reported "…visualization of the tip of the needle proved to be difficult in six cases…" in the supraclavicular block study [9] and an inability to visualize the target nerve in three of 20 subjects in the femoral nerve block study leading to one failed block [10]. In a follow-up study, the same investigators demonstrated higher overall block success for femoral nerve blocks and a lower required dose when US guidance is used [11].

In 2000, Ootaki and colleagues reported the use of US guidance as an alternative to the landmark-based approach for infraclavicular brachial plexus block in a series of 60 patients [12]. The authors' technique involved a 7-MHz linear array transducer and a 23-gauge needle; a local anesthetic was