Review Article

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Recent Advances in Brachial Plexus Anesthesia. A Review

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ABSTRACT

Brachial plexus anesthesia has been in vogue for more than 80 years. Of all the regional techniques that we perform, BPA remains the most challenging to anesthesiologists worldwide. It would appear that the risk and the incidence of complications of BPA are greater with supraclavicular approaches. Pneumothorax has almost disappeared as a complication and more attention is now being paid to respiratory impairment secondary to ipsilateral phrenic nerve paresis. The incidence of local anesthetic toxicity is greater with BPA than all other blocks and when one compares the incidence of systemic toxicity using the various approaches to the brachial plexus, there is a fourfold increase with supraclavicular methods. Clinicians are striving to find newer and better ways to achieve satisfactory BPA and the Plum bob and Mid- humeral methods are good examples of this. We are seeing a trend toward increased use of continuous BPA. More questions are being asked about the safety of deliberately seeking paresthesias for all peripheral nerve blocks. Regardless of the answer to that question, it is clear that brachial blocks should not be performed in anesthetised or heavily sedated patients. Those of us who perform regional anesthesia on a regular basis recognise the enormous benefits gained by patients when they opt for regional anesthesia. It is our duty to educate the public at large about the benefits of regional anesthesia. We must also take every precaution to prevent complications (*Rev Mex Anest* 1999;22:261-266).

Key Words: Regional anesthesia, brachial plexus, complications, technique, local anesthetics

RESUMEN

Avances recientes en la anestesia del Plexo Braquial. La anestesia del plexo braquial a estado en boga por más de 80 años. De todas las técnicas regionales que se han realizado, la anestesia del plexo braquial (APB) es la que representa mayores retos al anestesiólogo alrededor del mundo. Parece ser que el riesgo y la incidencia de complicaciones es mayor con abordaje supraclavicular. El pneumotórax casi ha desaparecido como complicación y se ha puesto mayor atención a la alteración respiratoria secundaria a la paresia unilateral del frénico. La incidencia de toxicidad por anestésicos locales es mayor con APB que con otros bloqueos y cuando se compara la incidencia de toxicidad sistémica comparando varios abordajes al plexo braquial, esta es cuatro veces mayor con el método supraclavicular, es por eso que se continua buscando nuevos métodos que sean más satisfactorios. La presente revisión describe los diferentes métodos y técnicas así como los beneficios y/o complicaciones derivadas de la APB (*Rev Mex Anest* 1999;22:261-266).

Palabras Clave: Anestesia regional, plexo braquial, complicaciones, técnicas, anestésicos locales

THE FIRST REFERENCE to the use of brachial plexus anesthesia (BPA) was made by William Halsted[1] in 1884 the very same year that Koller[2] introduced local anesthesia to the world. Halsted directly injected the brachial plexus during a surgical procedure in the supraclavicular region. Almost 30 years elapsed before the first practical application of BPA was described. In 1911 Hirschel[3] described a percutaneous approach to the brachial plexus using the axillary approach. The classic supraclavicular approach to the brachial plexus was described by Kulenkampff[4] in 1912 and in 1914 Bazy[5] described the infraclavicular approach to the brachial plexus. Numerous modifications of these three basic approaches have been described in the ensuing 80 odd years. The axillary approach to the brachial plexus is the most popular method used all over the world because it is technically easy to perform and to teach, is preferred by patients and the risk of pulmonary complications is least.

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Approaches to the Brachial Plexus

We have already alluded to the three basic approaches to the brachial plexus: supraclavicular, infraclavicular and axillary. Numerous variations of these three basic approaches have been described and most of them involve the supraclavicular region. These include: the parascalene, the anterior approach and the posterior approach. Two additional approaches have been described recently worthy of mention and these are the Plumb-bob[6] method and the Mid-humeral approach[7].

The Plumb-bob method

The patient is positioned in the supine position and a mark is made on the skin at a point just above where the clavicular head of the sternocleidomastoid muscle meets the clavicle. A needle is inserted at that point, at right angles to the floor and attempts are made to locate the brachial plexus. The needle is gradually redirected in a cephalic direction up to 30 degrees. If success is not achieved the needle is redirected up to 30 degrees in a caudal direction. Brown et al[6] have reported very high success rates using this approach and no major complications. This is an excellent approach when teaching beginners supraclavicular techniques.

The Mid-humeral method

Bouaziz[7] et al recently described the Mid-humeral approach to the brachial plexus. Following is a brief description of the technique: The patient is placed in the supine position. The axillary artery is palpated at the junction between the upper and middle third of the arm and marked. They recommend using nerve stimulation. The block is performed with the operator in the sitting position. The four major nerves are approached from a single needle insertion. The main advantage of the Mid-humeral approach is that the nerves are widely separated, which greatly facilitates electro location using the nerve stimulator. hen the block is performed high in the axilla the nerves are clustered more closely together and selective blockade of individual nerves, using nerve stimulation, is more difficult to achieve because local anesthetic solutions permeate to adjacent nerves.

The search for the ideal approach to the brachial plexus continues. Ideally we need an approach that will allow rapid onset of anesthesia, devoid of complications. We have yet to achieve these goals.

Entry into the BP sheath

It is quite evident from anatomic studies that the brachial plexus is enveloped in a fibrous sheath, extending from the origin of the brachial plexus down to the mid portion of the forearm[8]. Winnie[9] recommended single injection techniques for BPA based on this theory. He suggested that provided a needle was correctly placed in the sheath, all brachial blocks should work in time. He suggested that multiple injections exposed patients to an increased risk of nerve damage. Winnie's theory was challenged by Thompson et al[10] who suggested that each nerve had its own separate sheath and that high success rates could only be achieved by blocking each individual nerve. It appears that both of these masters were correct. The sheath is not one uniform space. There are multiple connections within the sheath[11], but they offer no impediment to the flow of local anesthetics.

A number of methods are used to verify correct needle placement in the sheath. The most common method used is the paresthesia method popularised by Moore and Bonica almost 50 years ago. This method relies on the slow advancement of a small gauge needle (25 G) until the patient experiences a sensation of numbness in the distribution of the nerve that has been encroached upon. This method has withstood the test of time and in most cases is a very reliable way of verifying correct placement of a needle in the brachial plexus sheath.

Nerve stimulation methods are being used increasingly to verify correct needle placement in the BP sheath. This method is a more objective way of determining whether a needle is in the sheath or not. The operator advances a needle towards the sheath and applies an electrical stimulus in the range of 2-3 mAs. When a motor response is observed the milliamperage is reduced to at least 0.5. If a good motor response is observed using 0.5 milliamps or less the likelihood of being in the sheath is high.

The transarterial method may be used in the axillary region. Penetration of the axillary artery is a good indication that a needle has been correctly positioned in the axillary sheath because the radial artery is in the epicentre of the axillary portion of the BP sheath. How safe is this method? Stan et al[12] have recently shown that this is a very safe method, with minimal complications and a high success rate.

Broadman et al[13] have recently shown how ultrasound can be used to verify correct needle placement in the sheath and how individual nerves can be identified in this manner.

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Probably the least reliable way to determine that a needle is in the sheath is the "click method", which relies on one's ability to detect a loss of resistance as a needle enters the sheath. Most experienced regional anesthesia experts have little problem identifying the BPS, however neophytes may experience considerable uncertainty in the beginning. None of these methods are fool-proof. It is difficult to elicit paresthesiae in some cases and a motor response cannot always be reliably obtained in every case. Sometimes it is not possible to detect a motor response using the threshold value of 0.5mA. Diabetic patients may respond differently to nerve stimulation and paresthesiae[11] which may explain why it is difficult to elicit paresthesiae in some patients, however these methods are reliable in most cases.

Rodríguez et al [15] recently described a very interesting new method of verifying needle placement in the BP sheath. They used cold saline which upon injection into the brachial plexus sheath elicited a very distinctive paresthesia: To my knowledge the "cold paresthesia" is the only way to elicit a paresthesia without actually touching a nerve with a needle

Matching anatomic approach with the surgical procedure

Supraclavicular approaches are most suitable for shoulder and upper arm procedures because it is difficult to achieve adequate anesthesia of the shoulder unless one blocks the lower portion of the cervical plexus. Mid-arm procedures may also be performed using all supraclavicular procedures, however Schroeder[16] et al recently demonstrated that mid-arm procedures (elbow) can be readily performed using the axillary approach.

Forearm and hand procedures can be performed using any of the three basic approaches, however we recommend the axillary approach, which has fewer complications

In view of the increased risk of complications associated with supraclaviclar approaches it is probably wise to use this approach only when there are clear indications.

Local anesthetics

Local anesthetics should be selected based on the requirements of the procedure. If brachial blocks are being performed in an ambulatory setting for surgical procedures local anesthetics with a short latency should be used, eg. lidocaine and mepivacaine. If brachial blocks are being performed primarily for pain control, longer acting drugs should be used, eg. ropivacaine or bupivacaine. The mg dose and the volume of local anesthetic drugs are important. A volume of up to 50 ml is recommended for axillary blocks and a dose of lidocaine with epinephrine (or its equivalent) up to 900 mg can be safely used in adults[17-19]. The maximum concentration of lidocaine recommended is 1.5%. Volumes in the range of 30-40 ml are recommended for supraclavicular blocks. The same principles apply when using longer acting drugs. Seeing that the largest doses of local anesthetic drugs are used for brachial blocks and the highest incidence of toxicity is reported with these blocks, local anesthetics with a more favorable toxicity profile such as ropivacaine, are preferable. Doses of ropivacaine up to 300 mg can be safely administered in adults for brachial blocks[20]. The minimum concentration of ropivacaine recommended for brachial blocks is 5mg/ml.

Continuous BPA

Ansbro first performed continuous BPA in 1946[21]. He used the supraclavicular approach and the metal needles used were held in place by a cork. There have been numerous reports of continuous BPA since that time[22-26]. The three basic approaches, supraclavicular, infraclavicular and axillary have all been used with varying success. Numerous over-the-needle and through-the-needle devices have been tested. One of the major problems with continuous techniques is maintaining the catheter in place. The risk of complications is greater with continuous methods because the needles used to place catheters are usually of a larger gauge. The risk of local anesthetic toxicity is also increased because continuous infusions of local anesthetic drugs are used sometimes over several days. The risk of neurologic injury is also greater with continuous methods because larger gauge needles are usually used. Patients are also exposed to an increased risk of infection with indwelling catheters. Finally, success rates with continuous techniques are usually lower than those reported with continuous methods. Continuous techniques are used for a number of reasons including: control of intractable pain, continuous passive motion, improved blood supply to the upper extremity following limb reattachment and post operative pain control. The infraclavicular method first described by Bazy and subsequently modified by Raj et al[27] is particularly suitable for continuous brachial plexus anesthesia. Continuous catheters are more readily

secured and are less encumbering to patients similar to subclavian central venous catheters. There is a trend toward increased use of continuous brachial plexus anesthesia in modern practice.

Complications of BPA

The risk of pneumothorax was a major impediment to the use of supraclavicular approaches to the brachial plexus for many years. De Jong[28] indicated that there was radiologic evidence of pneumothorax in as many as 25% of brachial blocks performed using the supraclavicular approach. Brand[29] reported a 6.1% incidence of clinically significant pneumothorax in a large teaching hospital. Winnie's [30] description of the interscalene and subclavian perivascular approaches to the brachial plexus in the early seventies renewed interest in supraclavicular approaches because the risk of pneumothorax was very low when these techniques were performed properly. Ramamurthy[31] reported a zero incidence of pneumothorax in 237 patients following the subclavian perivascular approach.

Anecdotal reports of phrenic nerve paresis have appeared in the literature sporadically since Kulenkampff's first description. Urmey[32] recently documented a 100% incidence of this complication following interscalene blocks. Other investigators have confirmed this observation and determined that it occurs with all supraclavicular approaches to the brachial plexus. The impact of phrenic nerve paresis is still being evaluated. Urmey has shown a 25% reduction in pulmonary function in healthy patients following interscalene block. Pere[33] reported similar findings. Fujimura[34] demonstrated a significant but not clinically significant decline in oxygen saturation following interscalene block (ISB). Based on this new information it would be wise to avoid all supraclavicular approaches to BPA in patients with even moderate impairment of pulmonary function. Ironically these were the very cases that brachial blocks were recommended for in the past. Respiratory symptoms have been reported in healthy patients and have been attributed to ipsilateral phrenic nerve paresis.

The routine use of nerve stimulation for peripheral blocks was popularized by Raj and attracted a number of new practitioners into regional anesthesia. There are no data to suggest that nerve location using nerve stimulation is safer or more efficacious than the paresthesia method however it does preclude the requirement to actually touch a nerve in order to verify accurate needle placement. The debate about nerve injury in association with BPA continues. Recent data from France [35] suggests that serious permanent injury to neural structures occurs rarely following BPA. We should also be aware that not all injuries to the brachial plexus are caused by needles or local anesthetics. Pre-existing injury, patient position, surgical trauma, tourniquet pressure and co-incidental viral disease, may independently cause injury to the brachial plexus. Selander[36] and Rice[37] present conflicting data about the importance of bevel configuration. It is difficult to referee these opposing opinions. Kulenkampff recommended "that only a very fine needle should be used" when performing BPA. This advice is probably more important than any debate about bevel design. Selander et al[38] have shown that local anesthetics and additives can cause nerve injury. Larger volumes of dilute solutions are recommended instead of smaller volumes of concentrated local anesthetics. Intraneural injections can cause serious disruption of neural tissue not just from needle trauma but also from pressure generated during injection[39]. Patients experience excruciating pain during intraneural injections and these warnings should not be ignored. Therefore BPA should be avoided in anesthetized patients. Recent data from the Closed Claims Study (CCS) [10] in the US have shown that juries are more likely to find in favour of the plaintiff in nerve injury cases, even when there is no apparent deviation from the standard of care. It is difficult to assess the significance of paresthesiae on the overall incidence of nerve injury. However Auroy's study convincingly demonstrated that paresthesiae were a consistent precursor in a high percentage of nerve injury cases involving peripheral neural blockade. It is evident again from the CCS that it is difficult to discern the etiology of a significant number of nerve injury cases. Nerve stimulation methods have been incriminated in nerve injury cases also. Moore[11] reported six medical - legal cases in which nerve injury occurred when nerve stimulation was used in anesthetised patients. The literature is peppered with anecdotal reports of nerve injury following BPA. Unfortunately some of the most serious cases never reach the literature for legal reasons. What we have learned from the literature that is available, including anecdotal reports, is that paresthesiae and pain on injection are consistent precursors in serious nerve injury cases, therefore general anesthesia and deep sedation should be avoided when performing BPA. Secondly excessively long needles have been associated with a number of nerve injury cases[12].

The highest incidence of local anesthetic toxicity associated with regional anesthesia has been re-

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ported with brachial blocks[43]. The incidence varies between 1.4%[44] and 0.2%[45] depending upon the reporter. The incidence of toxicity is three to four times higher when supraclavicular techniques are used. Accidental intravascular injection is the most common cause of systemic toxicity. Kozody[46] has shown that as little as 2.5 mg of bupivacaine injected into the vertebral artery can cause systemic toxicity. Tucker at al[47] have shown that the absorption of local anesthetic drugs from the brachial plexus is very slow compared with other sites. The maximum recommended dose of lidocaine with epinephrine for brachial blocks is 500 mg. Doses greatly in excess of these can be safely used. Larger doses of local anesthetic drugs enhance onset of action and prolong duration. Small incremental doses of local anesthetic drugs should be used at all times (5 ml) and bolus injections should be avoided.

Failure to achieve satisfactory anesthesia in all nerves of the brachial plexus is a common observation. Success rates vary between 70% and 99%. The incidence of failure appears to be higher with axillary approaches probably because the major nerve trunks are more widely separated in that region. The main reason for failure is slow onset of action.Up to 60 minutes are required to achieve anesthesia in all nerve trunks of the brachial plexus using a single injection technique in the axillary region. A number of methods have been used to enhance onset of action of local anesthetic solutions, including the use of carbonated local anesthetic solutions, alkalinization of local anesthetics, the addition of hyaluronidase. The most effective ways to enhance onset is to selectively block all nerves supplying sensory fibres to the operative site and to use generous doses of local anesthetic drugs. Single injection techniques are more effective in the supraclavicular region where the nerve trunks are more closely arranged. Combined interscalene/axillary approaches have been used to provide rapid onset anesthesia[48]. The ulnar nerve is frequently spared when performing interscalene blocks and the musculo cutaneous when performing axillary blocks. The likelihood of blocking both of these nerves increases when the two approaches are combined.

Numerous other complications have been reported following BPA including: total spinal anesthesia, epidural anesthesia, bronchospasm, unilateral deafness, Todds paralysis, vascular compromise, cardiac arrest respiratory failure and death, but fortunately these complications occur rarely. The overall incidence of complications associated with BPA appears to be higher with supraclavicular approaches.

Conclusions

Brachial plexus anesthesia has been in vogue for more than 80 years. Of all the regional techniques that we perform, BPA remains the most challenging to anesthesiologists world wide. It would appear that the risk and the incidence of complications of BPA is greater with supraclavicular approaches. This observation is based on a review of the literature during the past 25 years. This is not surprising especially when one considers that supraclavicular injections are made into highly vascular areas in close proximity to the central neuraxis. Pneumothorax has almost disappeared as a complication and more attention is now being paid to respiratory impairment secondary to ipsilateral phrenic nerve paresis. The incidence of local anesthetic toxicity is greater with BPA than all other blocks and when one compares the incidence of systemic toxicity using the various approaches to the brachial plexus, there is a fourfold increase with supraclavicular methods. Clinicians are striving to find newer and better ways to achieve satisfactory BPA and the Plum bob and Mid- humeral methods are good examples of this. We have more information about the pharmacology and pharmacokinetics of local anesthetics and they are being used more effectively in BPA. We are seeing a trend toward increased use of continuous BPA. More questions are being asked about the safety of deliberately seeking paresthesias for all peripheral nerve blocks. Regardless of the answer to that question, it is clear that brachial blocks should not be performed in anesthetised or heavily sedated patients. Ironically, physicians appear to be more blameworthy in nerve injury cases than others in the eye of the public, even when appropriate care has been provided. Those of us who perform regional anesthesia on a regular basis recognise the enormous benefits gained by patients when they opt for regional anesthesia. It is our duty to educate the public at large about the benefits of regional anesthesia. We must also take every precaution to prevent complications. We should also heed Kulenkampff's excellent advice in the early days of regional anesthesia when he said ..."in order to avoid complications of BPA only a very fine needle should be used".

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