The "Axillary Tunnel": An Anatomic Reappraisal of the Limits and Dynamics of Spread During Brachial Plexus Blockade

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BACKGROUND: Various anatomic factors have been described as affecting the distribution of a solution injected around the brachial plexus. Using computerized axial tomography dye studies, we introduce a new concept.

METHODS: Ten patients with brachial plexus catheters sited using the bent needle supraclavicular technique were studied. After the catheter tip was located, 20 mL 50% diluted Omnipaque™ dye was injected through the catheter. The limits of spread of dye and patterns of dye distribution were described and quantified.

RESULTS: The brachial plexus is contained within, and closely surrounded by, rigid muscular and bony boundaries, which effectively create a tunnel. Tunnel unit volumes are small (5.21–9.5 cm^3), differing significantly from the volume of dye injected ($P < 0.001$), so spread must occur along the tunnel. Tunnel dimensions vary, with potential points of resistance at the apex of the axilla and in the subcoracoid region. Catheters placed for shoulder surgery, with tips located inferomedial to the medial edge of the coracoid process, were associated with 90% retrograde flow (95% C.I. = 83–97). Catheters placed for more distal surgical procedures, with tips located inferolateral to the medial edge of the coracoid process, were associated with equally antero- and retrograde flow.

CONCLUSIONS: We conclude that the brachial plexus is contained within a rigid-walled tunnel of variable dimensions, which we call the "axillary tunnel." The scapula/subscapularis complex, related to the subcoracoid point of resistance, may account for the differing patterns of dye distribution observed.

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A variety of anatomic factors have been thought to affect the spread of a solution injected around the brachial plexus, including the presence of a "sheath," (1) the head of the humerus (2), and the existence of septae within the plexus (3).

As part of an ongoing investigation into the bent needle technique of supraclavicular brachial plexus block (4), we sought to further examine the applied anatomy of the brachial plexus using computerized axial tomography dye studies.

The bent needle technique was originally developed to minimize the risk of pneumothorax with a supraclavicular approach to the brachial plexus. For shoulder surgery, motor response in either the deltoid, triceps, or brachioradialis muscles is the preferred end-point for block placement, and the catheter is advanced 6–7 cm deep to the insertion point. For surgery distal to the shoulder, motor response in either the flexors or extensors of the fingers is the preferred end-point for block placement, and the catheter is advanced 10–11 cm deep to the insertion point. The incidence of phrenic nerve block also appears to be extremely low with this technique (5).

METHODS

With IRB approval and written informed consent, 10 patients with functioning brachial plexus catheters *in situ* were enrolled in the study. Two patients had bilateral catheters. The catheters were sited using the bent needle technique (4). All catheters had been placed under nerve stimulator guidance. Dye studies were performed on the day after surgery, between 2 and 4 h after the previous administration of local anesthetic through the catheters. This ensured comfort for study patients and no tissue distortion from local anesthetic at the time of dye injection. For study purposes, a functioning catheter was defined as one associated with complete analgesia (Visual Analog Scale = 0/10) and loss of cold sensation in the nerve territories of the surgical site (axillary nerve for shoulder surgery (Group S); radial, median, ulnar, medial, and lateral antebrachial cutaneous nerves for distal to shoulder surgery (Group DS)).

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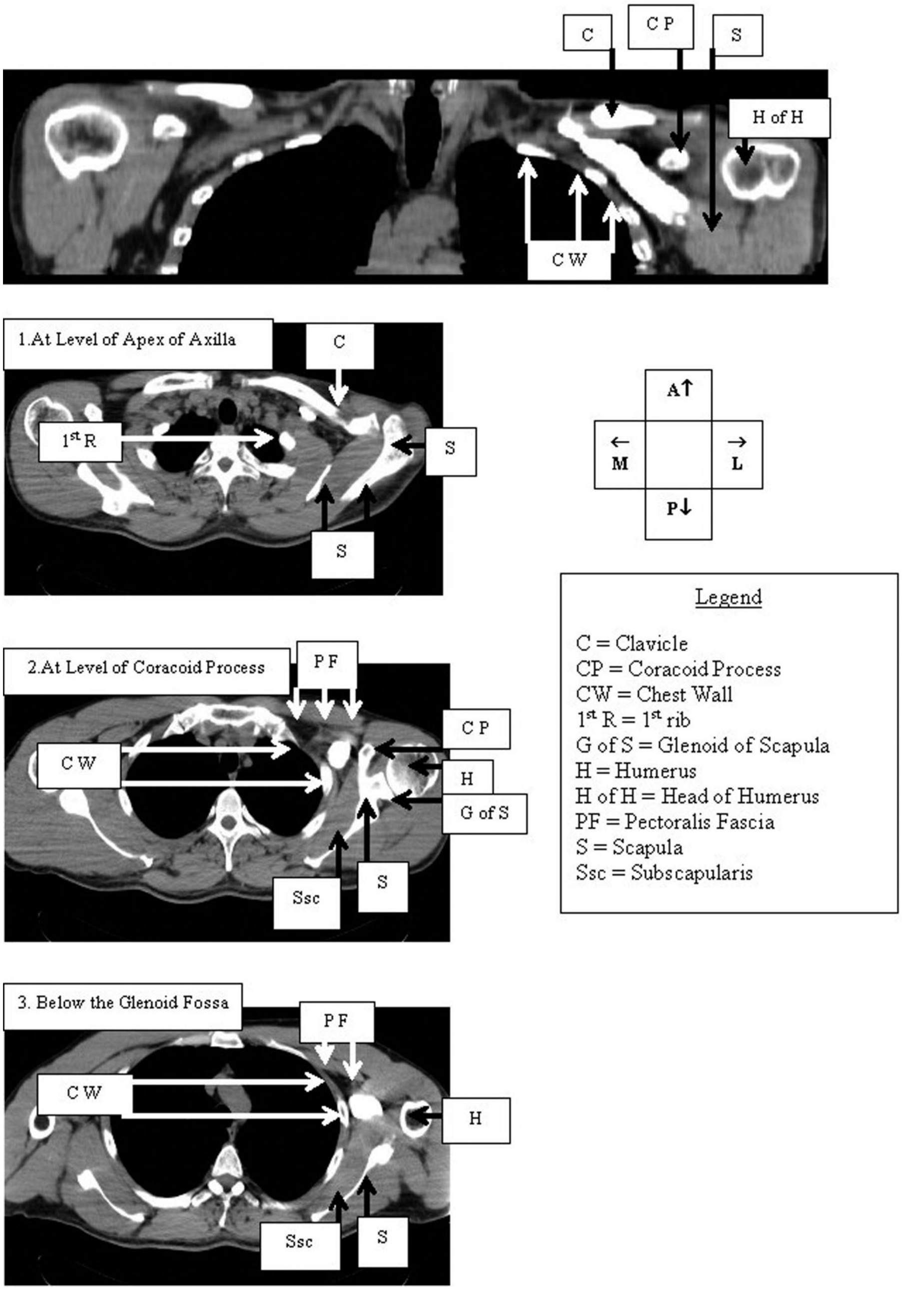

Figure 1. Boundaries of the axillary tunnel.

The course of the catheters and position of the catheter tips were determined by injecting 1 mL of 50% diluted Omnipaque™ radiocontrast dye through each catheter, followed immediately by computed tomography scanning, performed at a slice thickness of 3 mm, from the top of the coracoid process to the bottom of the glenohumeral joint.

For each study, 20 mL 50% diluted Omnipaque™ dye was injected through each brachial catheter over 30–45 s, followed immediately by computed tomography scanning, performed at a slice thickness of 3 mm, from the top of the clavicle to 30 mm below the glenohumeral joint.

The limits of spread of dye were described in axial and coronal sections (Fig. 1), and the dimensions of these limits were measured at specified levels: in axial section 1) Apex of axilla, 2) Lateral boundary of second rib, 3) Lateral boundary of third rib, 4) Lateral boundary of fourth rib; in coronal section 1) Clavicle–first rib, 2) Coracoid process–second rib, 3) Subscapularis–third rib, and 4) Subscapularis–fourth rib. In axial section, the compartment containing the dye was approximately triangular in shape. Since the area of a triangle is calculated as: [Delta] = ½ $b \times h$, where "b" is the base and "h" is the height, these measurements and calculations were made at each level. A unit volume was then calculated based on the volume of a prism, given by the formula [Delta] $\times\ l$, where l = length = 1 cm. Student's t-test was used to compare the unit volumes with the volume of dye injected, and with each other.

The pattern of contrast distribution relative to the catheter tip was examined and a percentage estimate

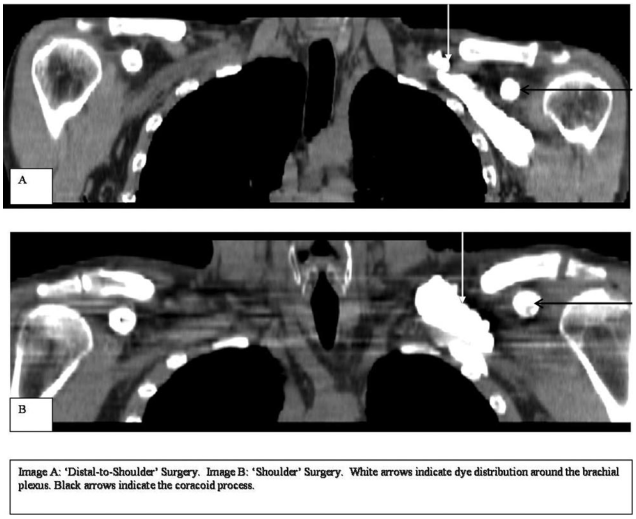

Figure 2. Patterns of dye spread—"distal-to-shoulder"(A) versus "shoulder"(B) surgery.

of antero- and retrograde flow was made. The pattern of cross-sectional dye distribution was noted and described.

RESULTS

There were six women and four men in the study, with an average age of 54 ± 21years and an average weight of 80 ± 15 kg.

In Group S (n = 4), the brachial catheter tips lay inferomedial to the medial edge of the coracoid process. In Group DS (n = 8), the catheter tips were inferolateral to the medial edge of the coracoid process.

In Figure 1, the dye spreads up to, but not beyond, the following rigid/semirigid structures:

1. Superiorly: trapezius muscle, clavicle, coracoid process of scapula, subscapularis muscle, head of humerus
2. Inferiorly: chest wall
3. Anteriorly: clavicle, pectoralis fascia
4. Posteriorly: scapula, subscapularis muscle
5. Medially: First rib and chest wall
6. Laterally: scapula, coracoid process and glenoid of scapula, humerus

The unit volumes of the anatomic compartment were as follows:

(a) clavicle–first rib (apex of axilla) = 5.21 ± 3.1 cm^3; (b) coracoid process–second rib = 9.5 ± 3.5 cm^3;

(c) subscapularis–third rib (subcoracoid) = 5.22 ± 1.76 cm^3; (d) subscapularis–fourth rib = 8.0 ± 2.0 cm^3.

The unit volumes (a)–(d) were significantly different to the 20 cm^3 volume of dye injected ($P < 0.001$). The unit volumes (a) and (c) were significantly different to the unit volumes (b) and (d) ($P < 0.001$).

In Group S, the dye flow was on average 10% anterograde (95% C.I. = 3–17) and 90% retrograde (95% C.I. = 83–97) (Fig. 2B), and occurred along the posterior aspect of the plexus (Fig. 2B). There was no anterior spread to the phrenic nerve. In group DS, the dye flow was on average 48% anterograde (95% C.I. = 34–62) and 52% retrograde (95% C.I. = 38–66) (Fig. 2A) and occurred in a central distribution (Figs. 1, 2, 2A). The retrograde flow did not reach the phrenic nerve in these studies.

DISCUSSION

We sought to better characterize the distribution of solution injected around the brachial plexus, prompted by the apparent clinical profile of the bent needle supraclavicular block technique.

Rigid and semirigid anatomic structures closely surround the neurovascular bundle from the apex to the base of the anatomic axilla (6), creating a rigid-walled compartment, pyramidal in axial section and conical in coronal section, which we have called the "axillary tunnel" (Fig. 1). Spread of injectate by expansion within the tunnel can only occur up to the boundaries of this tunnel and is limited at any one point along it, and therefore must go up or down it as determined by variations in dimension along it.

There were two points at which the unit volume of the axillary tunnel diminished significantly: in the apex of the axilla, and inferior to the coracoid process. Is it possible that these are points of resistance to flow? The lack of anterograde flow in Group S would support the notion of a hindrance to flow in the subcoracoid region. In the axial views, it is apparent that the scapula/subscapularis complex lies across the course of the plexus until the complex recedes posteromedially further down the axilla (Fig. 3). The catheter tips for Group S were placed medial to the glenoid of the scapula, and hence flow could have been influenced by the complex. The even distribution of flow in Group DS, together with the knowledge that the catheter tips were more laterally positioned, suggests that these catheters were located within the point of resistance. On this basis, we would suggest that the scapula/subscapularis complex is the cause of obstruction to flow at this level in the axilla, rather than the head of the humerus as has been previously suggested (2).

The patterns of flow may also account for the very low incidence of phrenic nerve block in an earlier series (5). In the current study, the dye in Group S spread retrogradely along the posterior aspect of the plexus (Fig. 2B), and was separate from the more anteriorly located anterior scalene muscle and associated phrenic nerve. In Group DS, the dye spread retrogradely throughout the plexus to the lateral margin of the first rib, without reaching the anterior scalene muscle and phrenic nerve (Fig. 2A). We suggest that avoidance of the phrenic nerve may have been both a function of distance of the point of injection from the phrenic nerve, and also the precise placement of the catheter within the tissue planes of the plexus.

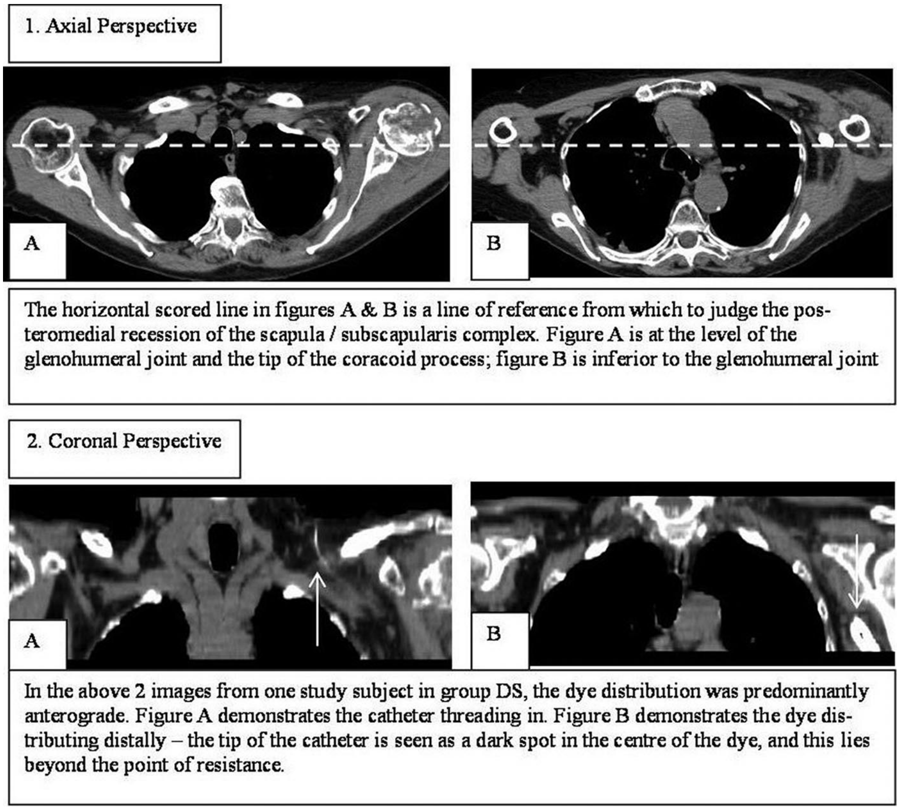

Figure 3. The scapula/subscapularis complex.

The brachial plexus sheath has been considered a cornerstone of many techniques, and at best it misrepresents the actual anatomy (7). It may be that the techniques have worked in spite of, rather than because of, this model. It would also be misleading to say that the traditional techniques, e.g., axillary, have been without their problems. We would suggest that improved modeling can explain at least some of these problems, and better guide needle placement and drug delivery. With the increased interest in continuous techniques, accurate understanding of the anatomy is important to guide catheter placement and control block profile. A new model delivers the opportunity for new and better techniques.

In conclusion, the brachial plexus is contained within a rigid-walled tunnel of variable dimensions, which we call the "axillary tunnel." The site of injection, both in terms of where it occurs along the length of the tunnel and where it occurs in the plexus complex, appears to be important for determining the spread and effect of an injected solution.

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