Review of Brachial Plexus Anatomy As Seen on Diagnostic Imaging: Clinical Correlation With Computed Tomography–Guided Brachial Plexus Block

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Brachial plexus block provides anesthesia to all deep structures from the shoulder to the hand and has been used to provide operative anesthesia,[1-3] achieve postoperative analgesia in the upper extremity,[4] and treat pain associated with invasive cancer through neurolytic brachial plexus block.[5] In a previous report by Mukherji et al,[6] a technique for computed tomography–guided (CT-guided) brachial plexus block and initial results for regional pain control were detailed in a series of 5 patients with difficult to identify surface landmarks.[6] The purpose of this report is to review the anatomy of the brachial plexus by use of representative CT images and magnetic resonance imaging (MRI). We review the technique of CT-guided neurolytic brachial plexus block as previously described by Mukherji et al[6] through a case report and images that describe a patient where normal landmarks were obscured by squamous cell carcinoma. We then review the normal anatomy of the brachial plexus relevant to regional anesthesia, as seen on both CT and MRI.

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Accepted for publication September 26, 2006.

Support was provided solely from institutional and departmental sources.

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1098-7339/07/3201-0001$32.00/0
doi:10.1016/j.rapm.2006.09.006

Case Report

A 63-year-old man with metastatic squamous cell carcinoma of unknown origin that involved the left brachial plexus developed near complete sensory and motor deficits in the arm, accompanied by severe constant burning and frequent lancinating pain in the entire arm. He had complete flaccid paralysis of the arm below the shoulder and severe allodynia to even light touch in the hand. His pain was poorly controlled on high doses of oral morphine and anticonvulsants. Brachial plexus neurolysis was considered in attempts to control his pain.

The area within the supraclavicular fossa directly overlying the tumor was firm and distorted. This condition was attributed to local tumor involvement and the effects of radiation therapy to the region. Neither the scalene muscles nor the sternocleidomastoid muscles could be identified by palpation. A decision was made to attempt the block by use of guidance with CT after informed consent was obtained. After the procedure, the allodynia and lancinating arm pain decreased from a preprocedure visual analog pain score of 8 to 4. This incomplete reduction of pain was likely caused by diffuse metastatic disease that could not be alleviated by this single procedure. A detailed description of the technique used for CT-guided brachial plexus block follows the discussion of the anatomy of the brachial plexus.

Anatomy of the Brachial Plexus

The brachial plexus is formed by the ventral rami of C5-T1, with frequent contributions from C4 and T2. The rami leave the intervertebral foramina, extending anterolaterally and caudally between the anterior and middle scalene muscles (Fig 1). At the

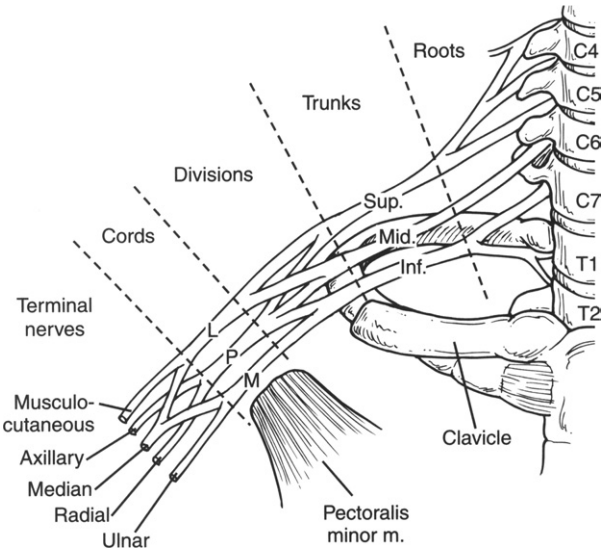

Fig 1. Anatomic layout of the brachial plexus. L, lateral; M, medial; P, posterior. (From Rathmell JP, Neal JM, Viscomi CV, eds. *Regional Anesthesia: The Requisites in Anesthesiology*, Philadelphia, PA: Elsevier; 2006. Used with permission.)

lateral border of the scalene muscles, they unite to form 3 trunks, which emerge from the interscalene groove and converge toward the upper surface of the first rib. The upper trunk is formed by C5 and 6; C7 forms the middle trunk; C8 and T1 form the lower trunk. At the lateral border of the first rib, each trunk divides into anterior and posterior divisions, passing inferior to the middle portion of the clavicle. As the trunks enter the axilla, they, in turn, divide to form 3 cords: lateral, medial, and posterior. The cords are so named because of their relation to the second part of the axillary artery. At the lateral border of the pectoralis minor muscle, the 3 cords give rise to the distal nerves of the upper extremity—the median, ulnar, musculocutaneous, axillary, and radial nerves.

CT and MRI of the Brachial Plexus

CT and MRI are two powerful tools available that greatly enhance visualization of the brachial plexus. MRI allows for clear and direct visualization with superior contrast resolution of all components of the brachial plexus from the nerve roots to the axillary cords.[7] Because it affords superior soft-tissue resolution and the ability to readily reconstruct images in multiple planes, MRI is the modality of choice for imaging the brachial plexus in search of anatomic abnormalities. Multiple imaging planes allow the capacity for MRI scans to examine the roots in the transverse plane, and the trunks and cords can be visualized in the coronal or sagittal plane. In coronal MRI reconstructions, a long portion of the course of the brachial plexus can be examined in a single image (Fig 2). The cervical nerve roots can be seen joining to form the trunks of the brachial plexus, just anterior and inferior to the middle scalene muscle over the cupola of the lung. In the transverse view, MRI clearly demonstrates the roots of the brachial plexus adjacent to the anterior scalene muscle and subclavian artery (Fig 3). Sagittal MRI demonstrates the anterior–posterior relation well (Fig 4). The brachial plexus is seen just between the anterior and middle

Fig 2. Coronal MRI demonstrating brachial plexus anatomy. The nerve roots can be seen as they join to form the trunks of the brachial plexus (BrPlex) over the anterior and inferior aspect of the middle scalene muscle (ScM) over the cupola of the lung. Other adjacent structures include the sternocleidomastoid muscle (SCM) and the vertebral artery (VertA).

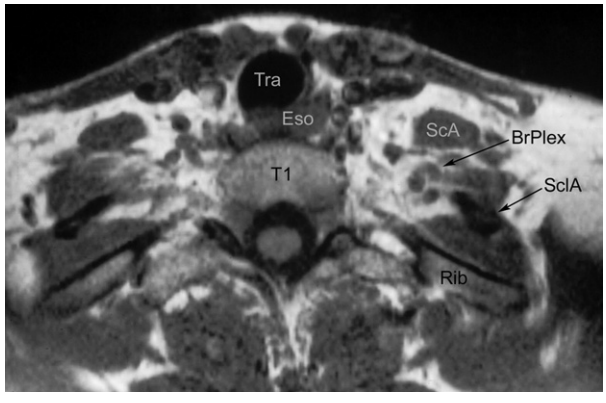

Fig 3. Axial MRI at the level of T1. The trunks of the brachial plexus (BrPlex) can be seen just posterior to the anterior scalene muscle (ScA) and medial to the subclavian artery (SclA) anterior to the head of the first rib. Compare the vast improvement in soft-tissue resolution on this MRI with that seen on CT in Figure 6.

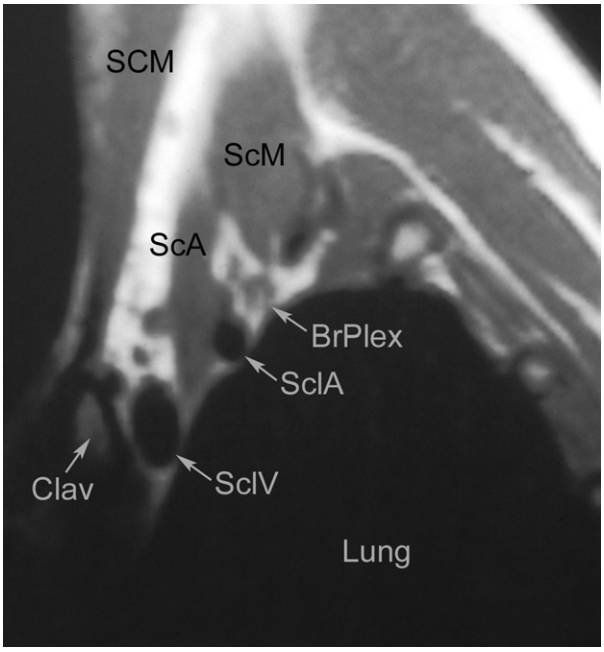

Fig 4. Sagittal MRI demonstrating the brachial plexus near the mid-clavicular line. The brachial plexus (BrPlex) can be seen over the cupola of the lung between the anterior (ScA) and middle (ScM) scalene muscles, just posterior to the subclavian artery (SclA). Note the location of the clavicle (Clav) and subclavian vein (SclV).

scalene muscles, posterior to the subclavian artery and directly overlying the cupola of the lung.

As an alternative, CT provides good contrast resolution and may be used both to visualize brachial plexus structures beyond the nerve roots and to demonstrate soft-tissue abnormalities/tumors located adjacent to the course of the brachial plexus. CT of the brachial plexus requires administration of radiographic contrast media to distinguish nerves from blood vessels.[7] The cervical nerve roots at all levels cannot be clearly discerned on CT because of signal attenuation (ie, the radiopaque bony vertebral structures obscure soft-tissue detail). However, axial CT at the vertebral body of C7 visualizes the ramus of brachial plexus between the scalene muscles and slightly posterolateral to the vertebral vein (Fig 5). At the level of T1, axial CT demonstrates the trunks of the brachial plexus between the anterior scalene muscle and the head of the first rib (Fig 6). Here, the trunks of the brachial plexus lie posterior to the subclavian artery. CT has the added advantage of providing sufficient resolution for accurate guidance when brachial plexus block is performed in patients in whom anatomic distortion prevents palpation of normal landmarks via a blind approach.

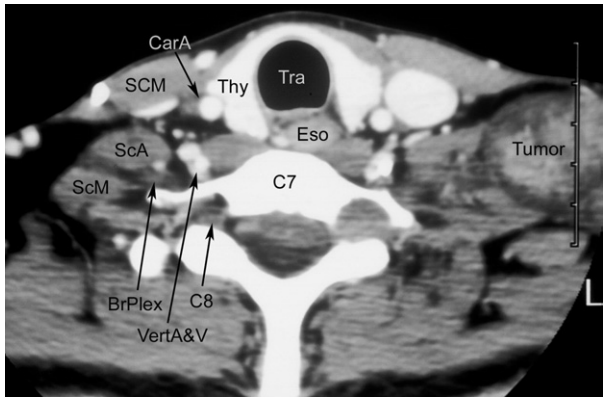

Fig 5. CT at the level of C7. The brachial plexus (BrPlex) lies anterior to the transverse process of C7, just medial to the groove between the anterior (ScA) and middle (ScM) scalene muscles. The vertebral artery and vein (VertA&V) lie just medial to the brachial plexus. Other adjacent structures include the sternocleidomastoid muscle (SCM), thyroid gland (Thy), trachea (Tra), and esophagus (Eso).

CT-Guided Brachial Plexus Block Technique

The four main approaches for brachial plexus block include supraclavicular, infraclavicular, interscalene, and axillary.[8] These multiple techniques all use common anatomic landmarks to approximate needle placement in the area around the brachial plexus. These techniques have been improved upon through eliciting paresthesias or through use of peripheral nerve stimulation, but both methods are potentially imprecise and contraindicated in some patients.[9] However, in-

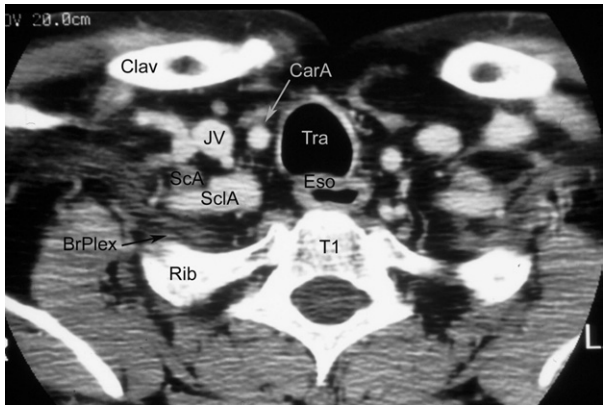

Fig 6. CT at the level of T1. The brachial plexus (BrPlex) lies posterior to the anterior scalene muscle (ScA), between the subclavian artery (SclA) and the head of the first rib. Other adjacent structures include the clavicle (Clav), internal jugular vein (JV), carotid artery (CarA), trachea (Tra), and esophagus (Eso).

stances occur when normal anatomic landmarks may be difficult to identify.[6] For example, surgery and radiation therapy or differences in body habitus can make palpation of landmarks difficult. The indications for CT guidance at our institution are inability to palpate normal surface landmarks because of body habitus or anatomic alterations caused by tumor infiltration or fibrotic changes from previous radiation therapy and for neurolysis of the brachial plexus. Blind brachial plexus block is also associated with several complications: pneumothorax, unintentional intravascular, spinal and epidural injection, vagus, and recurrent laryngeal-nerve injury.[4] To date, the only reported adverse events noted by the CT-guided approach are phrenic nerve palsy and Horner's syndrome. CT guidance also has the advantage of decreased analgesic dose through direct visualization and placement of medication on the nerve structures.[6]

In CT-guided brachial plexus block technique, the patient was placed supine in the CT scanner gantry, with the side of interest elevated at approximately 30° above the plane of the table and the head turned away from the area of interest. This position was utilized to place the angle of the needle insertion more perpendicular to that of the table. Scout films were attained at 3-mm increments from C5 to T1, and the anterior and middle scalene muscles are identified. In this case, the scalenes at the level of C5, toward the inferior aspect of the thyroid cartilage. Use of a radiopaque skin marker (barium paste), the point on the skin directly overlying the interscalene groove at C6 was identified and anesthetized with local anesthetic. A 22-gauge, 3-inch spinal needle was advanced in small increments to lie within the interscalene groove between the anterior and middle scalene muscles (Fig 7). After each needle advancement, a single CT image was obtained to assess the depth of the needle. With the needle in position within the interscalene groove, 5 mL of 12% phenol and 20 mL 0.25% bupivacaine hydrochloride in radiocontrast (iohexol 180 mg/mL) was injected and a repeat CT obtained to determine spread of the solution (Fig 8).

Fig 7. CT scan of case-report patient at the level of C6 demonstrating a 22-gauge needle in position between the anterior (ScA) and middle (ScM) scalene muscles. Other adjacent structures include the sternocleidomastoid (SCM) and the trachea (Tra).

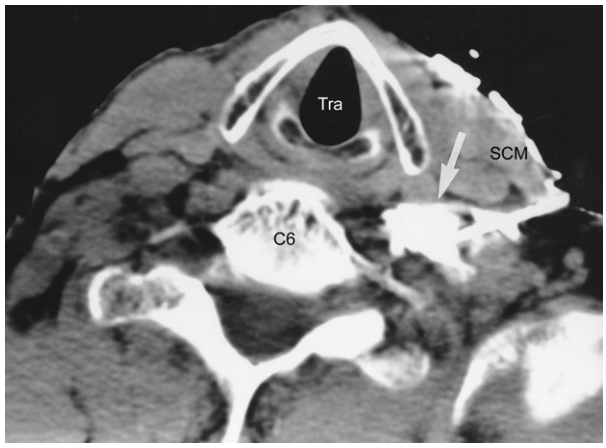

Fig 8. CT scan of case-report patient at the level of C6 demonstrating a 22-gauge needle in position between the anterior and middle scalene muscles after injection (arrow) of 5 mL of neurolytic solution (12% phenol in iohexol 180 mg/mL). Other adjacent structures include the sternocleidomastoid (SCM) and the trachea (Tra).

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