Thoracic Paravertebral Block

Essay

Submitted for Partial Fulfillment of Master Degree in Anesthesiology

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2012

Introduction

In the beginning of the 20th century, an anatomical area lateral to the spinal column was defined, the paravertebral space. Spinal nerves travel through this space as they become intercostal or lumbar nerves. Injection of small amounts of local anaesthetic solutions into this space produced unilateral analgesia of the trunk without any major physiologic derangement reported. The technique therefore became popular analgesic technique for procedures such as thoracoplasty and lobe resections during the tuberculosis era of that time ***(Karmakar, 2001).***

The thoracic paravertebral block is a technique of injecting local anesthetic in the vicinity of the thoracic spinal nerves emerging from the intervertebral foramen with the resultant ipsilateral somatic and sympathetic nerve blockade. The resultant anesthesia or analgesia is conceptually similar to a "unilateral" epidural anesthesia. Higher or lower levels can be chosen to accomplish a unilateral, band-like, segmental blockade at the desired levels without significant hemodynamic changes. This technique is one of the easiest and most time efficient to perform, but the technique failure rate reached 10.7% in adults and

6.2% in children. Certain details of technique are important if we wish to limit the incidence of failure rates. This block is performed in our practice most commonly for surgery in patients undergoing mastectomy, cosmetic breast surgery and thoracic surgery. A catheter can also be inserted for continuous infusion of local anesthetic, even in patients on anticoagulants ***(Hazelrigg et al., 2002).***

Indications of PVB include also chest wound exploration in a single lung transplant recipient, acute post herpetic neuralgia, and chronic pain management: benign and malignant neuralgia. In addition to miscellaneous indications such as fractured ribs, therapeutic control of hyperhidrosis, liver capsule pain after blunt abdominal trauma, therapeutic control of hyperhidrosis, endovascular abdominal aortic reconstruction ***(Harle and Ganapathy, 2008).***

The complications of PVB recorded were: inadvertent vascular puncture (6.8%); hypotension (4.0%); haematoma (2.4%); pain at site of skin puncture (1.3%); signs of epidural or intrathecal spread (1.0%); pleural puncture (0.8%); pneumothorax (0.5%) ***(Joshi et al., 2008).***

Aim of the work

The purpose of this essay is to discuss the most recent and relevant developments for the thoracic paravertebral block.

Anatomy

The thoracic paravertebral space (TPVS) is a wedged shape with the apex lying laterally and the base medially as shown in Figure 1 ***(Dodd and Hunsley, 2011).***

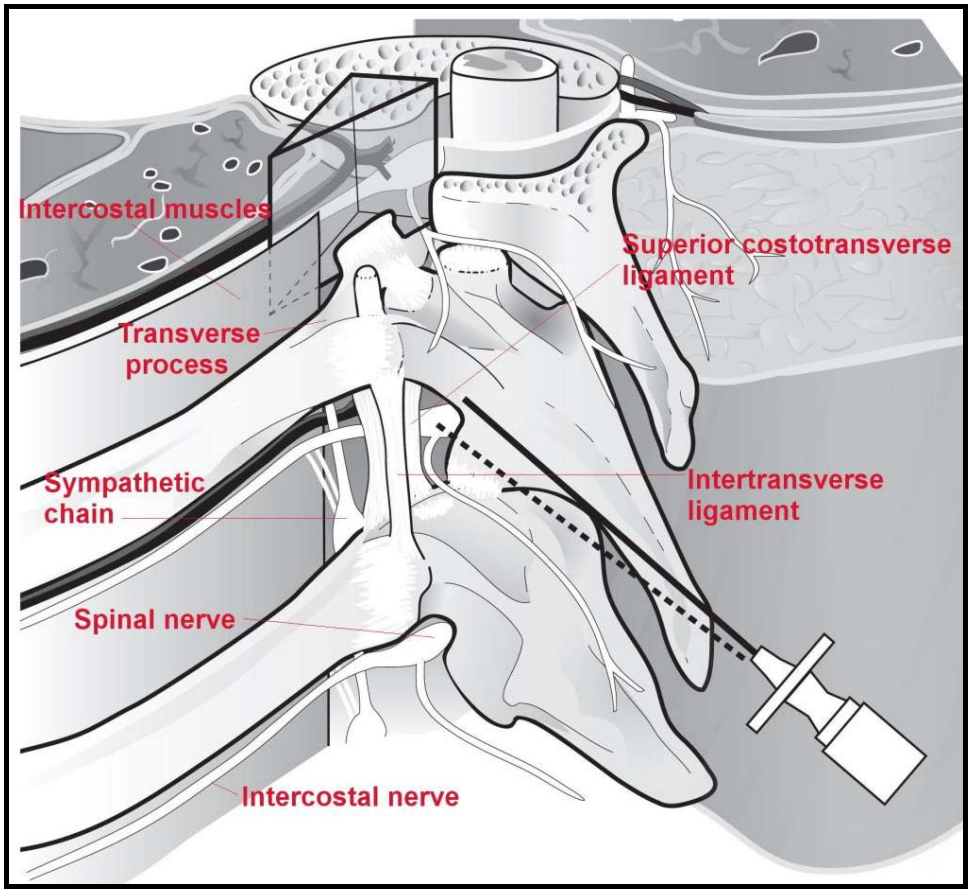

Figure (1): Drawing of the thoracic paravertebral space. The boundary of the space is depicted by a transparent wedge.

Relationships:

1. *Anterolaterally* (from posterior to anterior) lie the parietal pleura, the pleural space, visceral pleura and lung parenchyma.

2. *Medially* lies the postero-lateral portion of the vertebral body, the vertebral disc and the vertebral foreman with its corresponding spinal nerve.

3. *Posteriorly* the TPVS is limited by the superior costo-transverse ligament.

4. *Laterally* the space is bound by the posterior intercostal membrane and the intercostal space. ***(Dodd and Hunsley, 2011)***.

The nerve contents of paravertebral space are:

A- The spinal (Intercostal) nerve:

The intercostal nerves are the primary rami of T_1 till T_{11}. Many fibers of T_1 unite with fibers from C_8 to from the lower trunk of the brachia plexus. These fibers leave the intercostal space by crossing the neck of the first rib, while a smaller bundle continues on a genuine intercostal course ***(Dan and Gale, 1998).***

The only other notable variation in the intercostal nerves is the distribution of some fibers from T_2 and T_3 to the formation of the intercostobrachial nerve ***(Michael, 1996).***

Terminal distribution of this nerve is to the skin of the medial aspect of the upper arm. Somatic innervation of the area from the nipple to below the umbilicus is provided by segmental spinal nerves from T_4-T_{12}, while portion of the chest wall above the nipples has an overlapping innervation from the segmental spinal nerves of T_2 and T_3 and from peripheral branches from the cervical plexus (supraclavicular nerves, C_3 C_4) ***(Dan and Gale, 1998).***

As the incision for most thoracic and upper abdominal procedures generally do not extend above the T_4 dermatome, anaesthetizing of these nerves is not necessary. T_{12} is not an intercostal nerve because it does not run a course between two ribs; it might more appropriately be termed a subcostal nerve. Some of its fibers unite with fibers from the first lumbar nerve and are terminally represented as ilio-hypogastric and ilio-inguinal nerves ***(Robert and Molloy, 1999).***

A typical intercostal nerve has four significant branches: The first are the paired gray and white rami

communicates, which pass anteriorly to and from the sympathetic ganglion and chain. The second branch arises as the posterior cutaneous branch and supplies the skin and muscles in the paravertebral region. The third branch is the lateral cutaneous division, which arises just anterior to the mid-axillary line. This branch is of most concern to the anaesthesiologist because it immediately sends subcutaneous fibers coursing both posteriorly and anteriorly to supply skin of much of the chest and abdominal wall ***(Dan and Gale, 1998).***

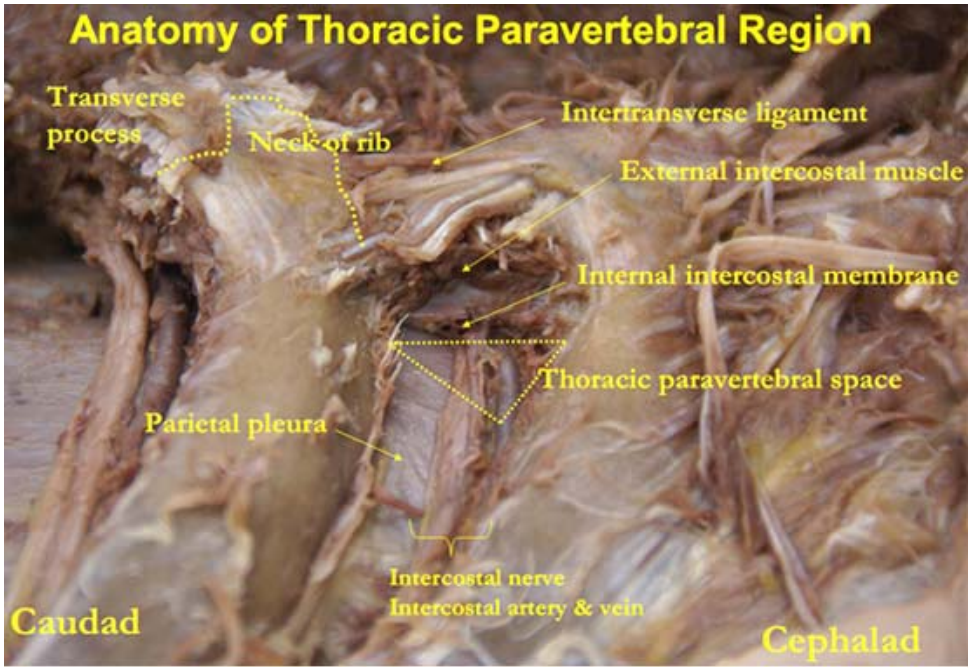

Figure (2): Anatomy of thoracic paravertebral region ***(Dan and Gale, 1998).***

The final branch of the intercostal nerve is the anterior cutaneous branch. In the upper five nerves, this branch terminates after penetrating the external intercostal and pectoralis major muscles to innervate the breast and the front of the thorax. But the lower six anterior cutaneous nerves terminate after piercing the sheath of the rectus abdominis muscle, to which they supply motor branches. Some final branches continue anteriorly and become superficial near the linea alba to provide cutaneous innervation to the midline of the abdomen ***(Kreuscher, 1990).***

In the paravertebral region, there is only fatty connective tissue between the nerve and the pleura, that is why with paravertebral block there is high risk of pneumothorax ***(Uioinpson, 1996).***

It is important to note that the spinal nerve as it emerges from the intervertebral foramen is devoid of fascial sheath and is often broken up into small nerve rootlets which are therefore easily penetrated by local anaesthetic ***(Nunn and Slavin, 1980).***

B- Sympathetic ganglion:

The preganglionic fibers of the sympathetic flow originate in the intermedio-lateral horn of the gray matter of the spinal cord. They exit the vertebral

foramen accompanying the anterior root of a thoracic nerve, just beyond the foramen, the sympathetic fibers go ventrally via the white rami communicates to the ganglia of the sympathetic chain. Some of the sympathetic outflow end in the segmental ganglion anastomosing with ganglionic fibers, others pass directly through the ganglion, still as preganglionic fibers ending in the collateral ganglia ***(Michael Mulroy, 1996).***

Within the sympathetic segmental ganglia, preganglionic and postganglionic fibers synapse. Some of the postsynaptic nerves return to their respective segmental nerves via the gray rami communicates, innervating blood vessels, sweat glands, and the pilomotor muscles of the skin. Other postganglionic fibers may run three to six dermatomes caudal or cephalic through the sympathetic trunks to terminate in more distal ganglia. Still others pass through the vertebral ganglia to end in a variety of nerve plexi, such as the cardiac plexus ***(Jordan, 1985).***

The positions of the sympathetic ganglia vary depending on the anatomic level of the spinal cord where they are found. The first thoracic sympathetic ganglion becomes, fused with the lower cervical

ganglion to form the inferior pole of the stellate ganglion ***(Raghavender, 1999).***

In general, as one descends from T_2 to L_2, the site of the ganglia move from beneath the rib to the antero-lateral surface of the vertebrate ***(Michael, 1996).***

The second thoracic ganglion lies just anterior to the medial portion of the neck of the rib. The next three or four ganglia lie in front of the corresponding head of the rib. The lower thoracic ganglia from T_2 to T_{10} are located just below the rib along the posterior superior surface of the vertebrate. The T_{11} and T_{12} ganglia are on the lateral surface of the vertebrae, approximately, whereas the lumbar ganglia move progressively more toward the antero-lateral surface ***(Jordan, 1985).***

The paravertebral area contains some loose extra-pleural fascia, also it has no lateral limit as it contains with the tissue plane between the intercostal muscles, so the distribution of the solution injected into the paravertebral space has been observed in cadaver studies by using either resin ***(Conacher, 1988)*** or colored dye ***(Crossley and Hosie, 1987).***

Resin was injected by ***Conacher in 1988*** into the thoracic paravertebral space of six cadavers to assess the suitability of this material for delineating the spread of injected substances in an area of the human body which was being re-evaluated currently as a repository for analgesic drugs.

The distribution and spread of the resin in relation to intercostal space, vertebral bodies and the spinal cord were noted, and compared with other studies radiologically ***(Conacher and Kokri, 1987)*** with contrast media and clinically with instillation of methelene blue at thoracotomy ***(Sabanathan et al., 1988).***

Cross anterior spread is not possible unless parietal pleura has been traumatized, however, contralateral spread anterior to the vertebral bodies occur; and this was proved by using contrast media; and this spread in the extra-pleural compartment of the thoracic paravertebral space along the sub serous fascial plane ***(Karmakar et al., 2000).***

There is some disagreement over the inferior limit of spread; the origin of psoas muscle probably prevents any spread below T_{12}. And this is described by

Lönnqvist and Hildingrson in 1992 and they found that the origin of the psoas major muscle completely seals off the paravertebral space below T_{12}. So the possibility of caudal spread of thoracic paravertebral block below this level through the paravertebral space would appear unlikely.

However, it was found that analgesia extends down in lumbar region; and this was proved by injection of 15ml crimson dye at region T_{11} ***(Saito et al., 1994).***

It was found that the dye enters abdominal cavity through medial and lateral arcuate ligament or through extradural spreas, so a somatic block of lumbar dermatomes has been seen to accompany a thoracic paravertebral block ***(Saito et al., 1999).***

Physiological Considerations

Voltage – Gated Ion channels:

Visualization of the sodium receptor and understandings of the molecular mechanisms of sodium channel binding and gating has the potential not only to advance local anesthesia and pain relief but also to the treatment of epilepsy and cardiac dysrhythmias. The unique anatomical features of nervous tissue provide long distance conduction of electrical signals without loss of information. Clustered within the nodes of Ranvier are voltage-gated sodium and potassium channels where electrical impulses are regenerated for propagation down the nerve. These channels are embedded in the lipid bilayer cell membrane that surrounds the axoplasm and cover the entire width of the nerve cell membrane ***(Catterall, 2002).***

1-Sodium channel:

The sodium channel protein is bell-shaped with four trans-membrane domains arrayed symmetrically around a central pore that splits into four passages that communicate between the intra and extracellular spaces .The four homologous domains (I-IV) contain six trans-membranous alpha helices (S1-S6) and an

inactivating particle connecting domains III and IV ***(Catterall, 2002).***

S5 and S6 segments, and the short loops between them form the pore, the fourth helix (S4) has positively charged arginine or lysine residues at every third position and is regarded as the "voltage- sensitive" region of the sodium channel. The cationic sites on S4 are postulated to be paired with anionic sites that may reside on nearby trans-membrane helices (S1- S3 or S5- S6) ***(Catterall, 2002).***

Three major conformational states, of the sodium channel exist, i.e. resting, open, and inactivated. In the resting state, the membrane potential is negative inside because of the presence of large concentrations of sodium ions outside the cel1 and relatively large concentration of potassium ions inside the cell. The S4 segments are in the "down" position, making the channel non-conductive. Outward movement and spiral rotation of the S4 segments through special, narrow-waisted pores in each domain, moves positive gating charges across the membrane's electric field and opens the ion channel. Subsequent channel inactivation involves the closure of a hydrophobic inactivation gate or motif called IFMT (isoleucine, phenylalanine,