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## Review Article

# Paravertebral blockade – Underrated method of regional anesthesia

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## ABSTRACT

**Introduction:** Paravertebral blockade (PVB) is an old, frequently forgotten and underrated method of regional anesthesia, with relatively few possible complications and an easy technique to perform.

**Aim:** The aim is to describe anatomy of paravertebral space (PVS), present history of PVB, its mechanism of action, indications and contraindications, techniques, with particular emphasis on identifying the PVS with the use of ultrasound and advantages of its use in various clinical situations.

**Material and methods:** This work was based on the available literature and the experience of the authors.

**Results and discussion:** Mechanism of action of PVB that includes somatic and sympathetic nerve blocks at a specific level, and requirements for its effectiveness and safety that rely on identification of anatomical landmarks, pressure differences, use of nerve stimulator, performed during thoracic surgery procedures, under visual control and ultrasound-guided, as a safe and accurate method with relatively the lowest number of complications, determines the use of this technique in the treatment of postoperative pain in certain clinical situations, as well as in breast surgery and hernia repair. Complications and adverse effects, including very rare, such as Harlequin syndrome, compared with complications of epidural anesthesia, confirm usefulness of this method of regional anesthesia.

**Conclusions:** (1) PVB is a technically simple and relatively easy to learn technique of regional anesthesia, with low incidence of complications and contraindications. (2) It may be successfully used in breast surgery, hernia repair, as well as in surgical debridement and revision of small, superficial thoracic wounds, in case of herpes zoster, rib fractures, bruised liver and several other clinical situations. (3) Its principal use is management of postoperative pain in thoracic surgery, where it should be used more often as an alternative to epidural anesthesia which entails multiple complications and is considered the gold standard in

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certain abdominal or breast surgeries. (4) The best quality of PVB is provided with placement of the catheter under direct vision during thoracotomy.

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## 1. Introduction

Paravertebral blockade (PVB) was first performed by Hugo Sellheim of Leipzig (1871–1936) in 1905, who aimed at finding an alternative of intrathecal spinal anesthesia, devoid of possible cardiovascular and respiratory complications. Also in Leipzig, surgical resident Arthur Läden (1876–1958) injected small quantities of procaine paravertebrally and mapped out the segmental innervation of the intra-abdominal organs, investigating not only pain relief, but also muscle relaxation within certain dermatomes. PVB was first described in 1919 by Kappis.<sup>1</sup> In the 1920s and 1930s it became popular and was a relatively easy method of anesthesia, alternative for imperfect at that time technique of general anesthesia, particularly in abdominal surgery and obstetrics, as well as in differential diagnosis and treatment of various clinical conditions, such as renal colic, biliary colic, angina, asthma, cancer pain, femoral neck fractures or muscular dystrophies.<sup>1</sup> Development and continuous improvement of techniques of general and perineural anesthesia contributed to the marginalization of PVB in the mid-twentieth century, so that this method soon become “more of interest to historians than practicing anesthesiologists.”<sup>2</sup> Another major blow to the enthusiasts of PVB were reported in 1940s cases of permanent nerve damage after subarachnoid administration of cinchocaine contaminated with phenol used for sterilization of glass ampoules, in which the medication was stored.<sup>3</sup> The concept of PVB has returned since 1979, when Eason and Wyatt prepared a modern description of paravertebral space (PVS), its contents and methods of percutaneous identification and demonstrated that PVB is an alternative to intrathecal anesthesia, safe, free of cardiovascular and respiratory complications, used in abdominal surgery and thoracic surgery both in adults and in children.<sup>4</sup> Despite that, its popularity is not large and frequency of use in the 1990s was approximately 3% in Poland.<sup>5</sup>

## 2. Aim

The aim of this work was to describe anatomy of PVS, present history of PVB, its mechanism of action, indications and contraindications, techniques, with particular emphasis on ultrasound-guided identification of PVS and advantages of the use of this technique in various clinical situations, as well as possible complications in comparison to epidural anesthesia.

## 3. Material and methods

This work was based on the available literature and the experience of the authors.

## 4. Results and discussion

Effectiveness of anesthesia is determined by correct identification of PVS, where local anesthetics are administered.

### 4.1. PVS anatomy

PVS is a wedge-shaped area positioned at the thoracic level, which has no definition in the textbooks of anatomy. It lies on both sides of the spine, is filled with loose connective tissue, anteriorly is limited by the parietal pleura, medially by vertebral body, vertebral disc and vertebral foramen, and posteriorly by superior costotransverse ligament and posterior intercostal ligament. Lack of superior and inferior limitation provides communication between upper and lower spaces. Laterally it is bound by intercostal spaces. Endothoracic fascia divides the PVS into two compartments: anterior – extrapleural and posterior – subendothoracic, importance of which has not been established.<sup>6</sup> Extrapleural compartment contains the sympathetic ganglion and subendothoracic compartment contains spinal nerve. Identification of endothoracic fascia that separates sympathetic trunk from posterior root ganglion with compartments might help to understand spread of the blockade and its frequent diversity.<sup>7</sup>

At the thoracic level PVS contains (Fig. 1): spinal nerve (intercostal, in the paravertebral segment devoid of myelin sheath), dorsal branches of the intercostal nerve, white and gray communicating branches and sympathetic trunk (anteriorly).<sup>8,9</sup>

### 4.2. Mechanism of action of PVB

Administration of a local anesthetic into PVS has a direct effect on the above mentioned neural structures located within this space. The result is a combination of somatic, motor and sensory blockade and unilateral sympathetic blockade of several adjacent dermatomes. Its number (extent of anesthesia) is dependent on the volume and concentration of the anesthetic used.<sup>10</sup> Eason and Wyatt claimed that 15 mL of 0.4% bupivacaine should block at least four adjacent dermatomes. Currently, it is assumed that a volume of 15 mL of 0.5% bupivacaine injected into the PVS results in somatic block of more than five dermatomes (1–9), accompanied by sympathetic block of more than eight dermatomes (6–10).<sup>11</sup> There are reported cases of unintentional block of both symmetrical sides of the body.<sup>8</sup> It results from the use of large volumes of anesthetic (>25 mL), high speed of administration or unintentional injection of anesthetic into the epidural space.<sup>12</sup> Rarely, bilateral planned PVB is used, particularly prior to abdominal surgeries.<sup>13</sup> Such PVB has also been described in a child after bilateral thoracotomy.<sup>14</sup>

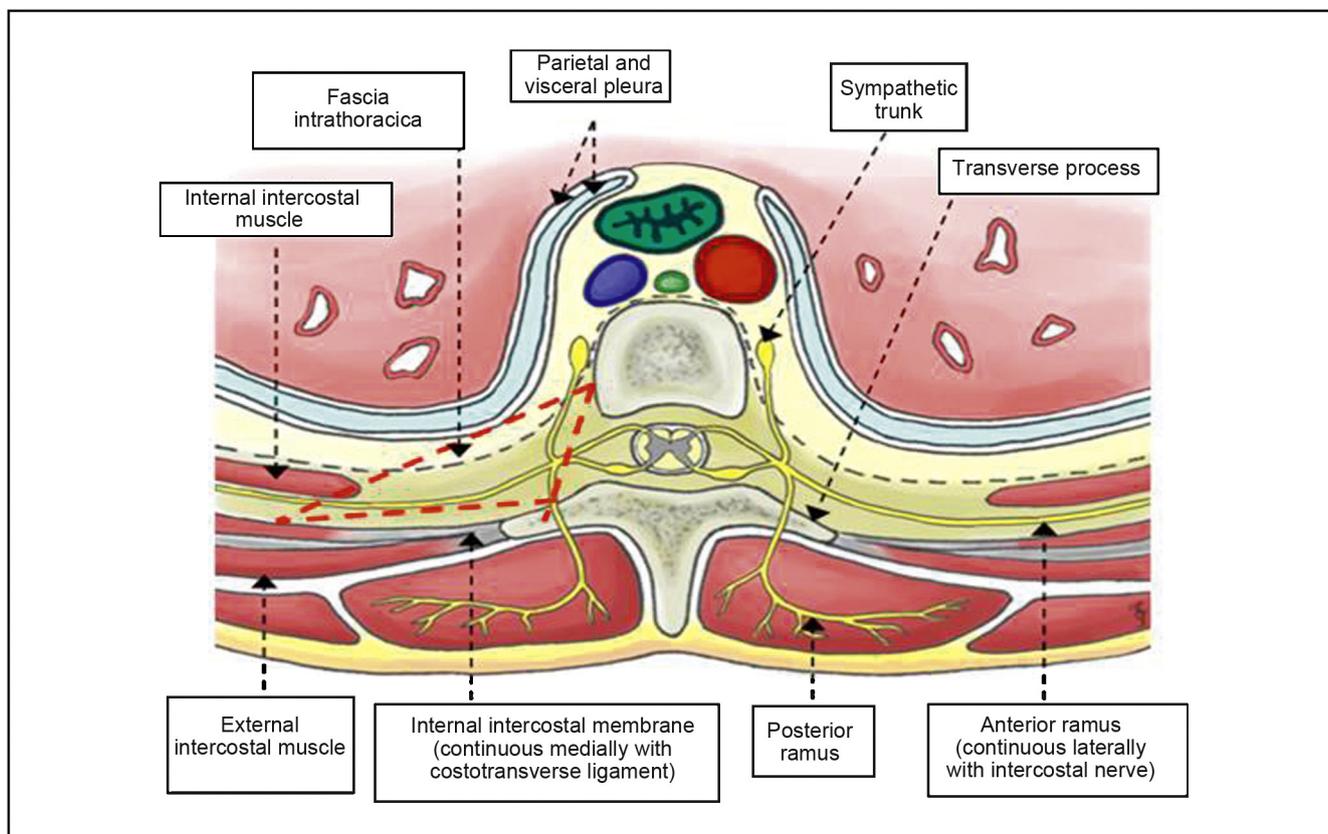


Fig. 1 – Anatomy of PVS.<sup>5</sup>

#### 4.3. Indications for PVB

PVB is recommended during postoperative analgesia (thoracic surgery, breast surgery, cholecystectomy, renal and ureteral surgery, hernia repair, appendectomy, minimally invasive cardiac surgery), anesthesia for surgery (breast surgery, hernia repair, surgical revision of wounds of thoracic wall), and acute zoster pain, chronic neoplastic neuralgias, rib fractures, treatment of hyperhidrosis and bruised liver.<sup>15,16</sup>

#### 4.4. Contraindications for PVB

PVB is absolutely contraindicated in case of infection of the skin and subcutaneous tissue on the side of anesthesia, hypersensitivity to anesthetic, presence of tumor in the paravertebral area. Relative contraindications for PVB include coagulation disorders, kyphoscoliosis and other deformations of the chest.

#### 4.5. Techniques of PVB

In clinical practice, there are various techniques of PVB: loss of resistance technique, landmark-based technique, nerve stimulator-guided, ultrasound-guided, during open thoracotomies.

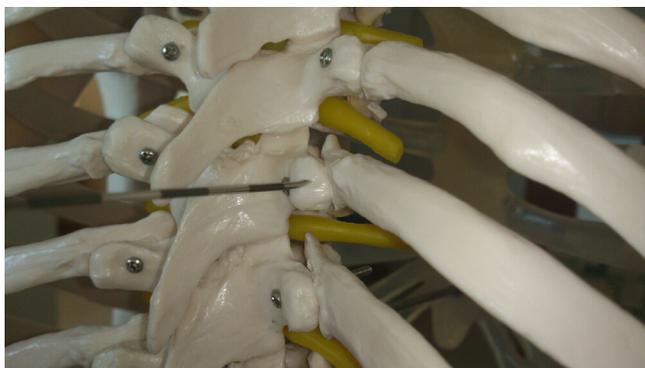
PVB is performed with the patient in seated or lateral decubitus position. Less commonly used is prone decubitus position. The back should be arched posteriorly, which increases the distance between spinous processes of adjacent

vertebrae, thus facilitating insertion of the needle into PVS without contact with transverse process. To identify spinal level and transverse processes the following anatomical landmarks are used: spinous processes, median line, angle of scapula, T7 level, paramedial line 2.5 cm lateral to the median line (Fig. 2).

After infiltration anesthesia of the skin under sterile conditions, the needle is inserted perpendicular to the skin 2.5 cm lateral to the median line in sagittal plane. The needle should never be positioned medially to avoid entering the

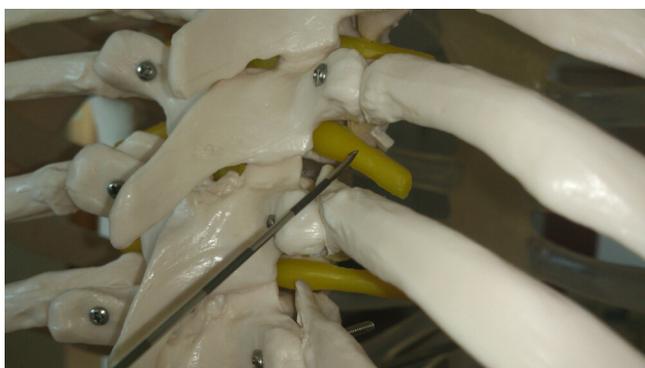


Fig. 2 – Location of external anatomical landmarks for PVB.

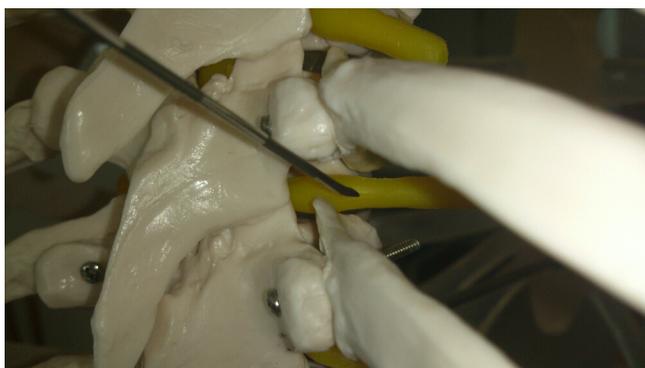


**Fig. 3 – Identification of the transverse process with Tuohy needle.**

intervertebral foramen and injection of anesthetic into the epidural or subarachnoid space.<sup>11</sup> On touching the transverse process (Fig. 3) the needle is withdrawn to the subcutaneous tissue and placed slightly with a cephalic (Fig. 4) or caudal direction (Fig. 5) and inserted again to walk off transverse process. The aim is to insert the needle 1 cm past the transverse process.<sup>17</sup> Through the needle 5 mL of local anesthetic should be administered to expand the PVS. Then, the total volume of local anesthetic is administered or the catheter is advanced to 5 cm beyond the tip of the needle. In case of single injection of the local anesthetic the volume is 5–15 mL. Continuous infusion through the catheter requires



**Fig. 4 – Cephalad orientation of Tuohy needle.**



**Fig. 5 – Caudal orientation of Tuohy needle.**

initial bolus of 0.50% ropivacaine, bupivacaine or levobupivacaine, followed by continuous infusion of ropivacaine (0.20%) or bupivacaine (0.25%) or levobupivacaine (0.25%) at a 10 mL/h rate. The catheter should be regularly checked for air, blood or cerebrospinal fluid. Occasionally, a slight loss of resistance may be felt as the needle passes through the costotransverse ligament.<sup>18</sup> When the placement of catheter is too easy, similar to insertion of the catheter into the epidural space, location outside the PVS may be suspected. In that case placement of catheter inside the pleural cavity, epidural or subarachnoid space may be suspected.

Various authors<sup>19</sup> suggest that loss of resistance should not be considered but to precisely measure skin-transverse process distance and simply advance the needle 1 cm deeper. Luyet in a cadaveric study demonstrated the presence of a gap between the lateral and medial portion of costotransverse ligament, which may be the cause of insertion of the top of the needle into the PVS without the audible click on passing through the ligament and no loss of resistance.<sup>19</sup> Depth of the transverse processes depends on the anatomy of the patient and spinal level on which PVB is performed. Distance from skin to transverse processes is the longest in upper thoracic level T1–T2 and lower lumbar L4–L5. In an average patient the distance is 6–8 cm. Closest to the skin (2–4 cm) are processes in middle thoracic spine T5–T10. Hill claims that this distance is 2–3 cm at T5–T6 and 5 cm at T1–T2.

Less frequently nerve stimulation for identification of PVS is used. Stimulation needle is connected to the nerve stimulator at current intensity of 2–3 mA, frequency of 2 Hz, pulse duration of 100–200 ms. When the tip of the needle is inserted into the PVS a motor response of intercostal muscles, muscles of the anterior abdominal wall and paraspinal muscles is observed. After PVB at the level of T4 in breast surgery assistant may be asked to put a hand in the axillary area at the side of procedure. Motor response of intercostal muscles may be easily observed. When PVB is performed on lower thoracic level motor response of muscles of the anterior abdominal wall is observed. Initially, when the stimulation needle is inserted through paraspinal muscles, direct stimulation of these muscles may be observed, which should not be taken into account. Regional spasm disappears after contact with transverse process. When the needle is inserted inside the PVS, current intensity should be reduced to 0.6 mA.

In recent years, there has been a growing interest in ultrasound-guided PVB. Through better identification of anatomical spaces, it allows to avoid complications resulting from the proximity of such structures as the pleural cavity or intervertebral foramina. Hara was the first to describe real-time ultrasound-guided PVB.<sup>20</sup> Once the ultrasound image in sagittal plane passing through PVS on T4 level was obtained, the author has identified transverse processes, ligaments (*ligamentum intertransversalis*, *ligamentum costotransversalis*) and pleura, measured the distance from the skin to these structures prior to PVB. The needle was then inserted with ultrasound guidance, using out-of-plane technique. The author has noted turbulence at the site of local anesthetic injection in all cases and forward movement of the pleura in 16% of cases. These changes may prove the correct placement of the tip of the needle in PVS during ultrasound-guided PVB. Hara equally interesting observation was the proper identification of pleura at T4 level and

difficulty in its identification at T1 level. The reason, according to Hara, may be deeper location of pleura at T1 than at T4 and lack of penetration of high-frequency probe of the deeper tissues.<sup>20</sup> Luyet in his cadaver study has suggested approach using ultrasound probe positioned in a longitudinal axis with a slight oblique tilt so that the upper part of the transducer is directed medially in longitudinal axis. The needle was inserted in-plane with the ultrasound probe and a catheter was placed with its tip in the PVS.<sup>19</sup> Shibata and Nishiwaki have used similar ultrasound approaches performed in real time.<sup>21</sup> High frequency probe was positioned in a transverse plane. The needle was inserted lateral to medial, until its tip reached the PVS. This space was identified as hypoechoic area between parietal pleura anteriorly and intercostal membrane posteriorly.<sup>22</sup> Proper administration of the local anesthetic was confirmed by observed anterior movement of the pleura and extension of the top of PVS. Because of insertion of the needle tangent to pleura, the possibility of pleural puncture is reduced. According to other authors such approach causes much pain and discomfort of the patient during needle insertion, particularly when performed on several levels. The cause may be a greater distance of the injection site from the PVS compared with the traditional method. There are also several other techniques, discussion of which is beyond the scope of this article.

In summary, ultrasound becomes an alternative way to identify the PVS and perform PVB compared to traditional landmark-guided method. Ultrasound allows to visualize the PVS prior to PVB, define the safe depth of needle insertion by determining the distance from the skin to transverse process and to pleura, as well as visualize in real time the spread of local anesthetic. The above aspects may translate into improved results, increased effectiveness of PVB, reduced complications. There is however the need to determine the optimal axis of ultrasound image and method of needle insertion (in-plane or out-of-plane), since the insertion itself remains rather difficult. Ultrasound is a useful tool in educational process, while demonstrating the PVS anatomy might improve the learning curve.

Safe, but unappreciated by thoracic surgeons, is visual-guided placement of PVB catheter during thoracic surgeries. Direct intraoperative access to the PVS structures allows safe placement of catheter for continuous PVB, visual control of its patency and position through administration of solution directly after insertion and initiation of postoperative analgesia already on the operating table, immediately after closure of the intercostal space.<sup>23,24</sup>

#### 4.6. Complications and undesirable effects of PVB

There are relatively rare and vary from 0% to 6.8%, by different authors.<sup>25</sup> Failure (lack of analgesia) occurs in about 6.8%–10.1% of anesthesia, and more frequently it concern adults than children.<sup>26</sup> In a large prospective study by Lönnqvist, which included 367 cases (adults and children), 4.6% of cases of blood pressure reduction, 3.8% vascular puncture, 1.1% pleural puncture and 0.5% of cases of pneumothorax were observed.<sup>26</sup> Unintentional pleural puncture may lead to pneumothorax,<sup>27</sup> although not necessarily.<sup>13</sup> Usually, it is a minor pneumothorax, that requires no surgical treatment (drainage) and only radiological control to prevent further accumulation of air.<sup>27</sup>

Hypotension in normovolemic patients is rare, particularly due to unilateral blockade of only several segments innervated by sympathetic nervous system. Occasionally, hypotensive effect is observed as a result of vasovagal reaction.<sup>28</sup> PVB during thoracotomy provides greater hemodynamic stability in comparison with epidural blockade, requires lower doses of vasopressors and colloids to maintain adequate oxygenation.<sup>29</sup> Incorrect technique of PVB may result in administration of anesthetic into the epidural space (needle placed too medially).<sup>30</sup> It is usually manifested by block of 1–2 contralateral dermatomes, very rarely bilateral block.<sup>13</sup> Spread of anesthesia in cervical space may cause paralysis of the stellate ganglion and preganglionic fibers and in consequence Horner's syndrome, unilateral<sup>31</sup> or bilateral.<sup>13</sup> A case report of development of Harlequin syndrome after PVB is also known.<sup>32</sup> Harlequin syndrome was manifested by unilateral diminished erythema and hyperhidrosis of the half of face and contralateral Horner's syndrome. Symptoms occurred after PVB for breast surgery.<sup>32</sup> Fagenholz et al.<sup>4</sup> have described a case of systemic toxicity of local anesthetics after PVB. During thoracotomy a catheter was surgically inserted into the PVS and in perioperative period infusion of bupivacaine (0.1%) with occasional boluses was used. On the second postoperative day the patient had seizures, symptoms of acute respiratory failure due to aspiration of gastric contents. Serum level of bupivacaine was 8 mg/L (normal range below 3 mg/L). Fagenholz et al. suggest that in case of continuous PVB bupivacaine doses of 2 mg per 1 kg of body weight per 4 h should not be exceeded, and only a limited number of boluses should be administered per day. When determining infusion rate, pharmacodynamic of bupivacaine, possible  $\alpha_1$ -acid glycoprotein deficiency due to deterioration of synthetic function of the liver caused by chronic alcoholism, and the use of less toxic local anesthetics (ropivacaine and levobupivacaine) should be considered. Barrington<sup>33</sup> defined the risk of local anesthetic systemic toxicity of PVB as 3.68 per 1000 procedures. In case of PVB there is no risk of serious complications of epidural blockade, spinal puncture or epidural hematoma.<sup>13</sup> Therefore, clotting disorders or anticoagulant treatment are only a relative contraindications to its performance. There are also no complications typical for epidural anesthesia, such as nausea, urinary retention, reduced mobility of postoperative patients and respiratory disorders.<sup>13</sup>

## 5. Conclusions

1. PVB a technically simple and relatively easy to learn technique of regional anesthesia, with low incidence of complication and contraindications.
2. It may be successfully used in breast surgery, hernia repair, as well as in surgical debridement and revision of small, superficial thoracic wounds, in case of herpes zoster, rib fractures, bruised liver and several other clinical situations.
3. Its principal use is management of postoperative pain in thoracic surgery, where it should be used more often as an alternative to multiple complications epidural, which is considered the gold standard in certain abdominal or breast surgeries.
4. The best quality of PVB is provided with placement of the catheter under direct vision during thoracotomy.

## Conflict of interest

None declared.

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