Paravertebral blockade (PVB) is a regional anaesthesia technique whereby local anaesthetic is administered inside the paravertebral space (PVS). The PVS is wedge shaped with the parietal pleura as anterolateral boundary, the posterolateral aspect of the vertebral body, the intervertebral disc and foramen as the base, and the superior costotransverse ligament (SCTL) that is located between the lower border of the transverse process above and the upper border of the transverse process below and its lateral continuation, and the internal intercostal membrane (IIM) as posterior boundary. The PVS is divided into an anterior, extrapleural, and a posterior, subendothoracic, compartment by the endothoracic fascia, which is closely applied to the ribs and fuses medial to the perist and the midpoints of the vertebral bodies. The PVS contains fatty tissue, spinal nerves, dorsal rami, rami communicantes, the sympathetic chain, and intercostal vessels.

Multiple indications for PVB have been reported, including surgical anaesthesia for breast surgery,1–4 surgical anaesthesia and postoperative analgesia during and after thoracic5 and abdominal surgery,6 and pain therapy for fractured ribs,7–10 postherpetic neuralgia,11 12 hyperhydrosis,13 and liver capsule pain after abdominal trauma.14 Several methods of PVB have been described. A loss-of-resistance technique with the SCTL as target structure was described by Eason and Wyatt.15 Greengrass and colleagues16 described a technique whereby the transverse process is initially contacted by the needle with subsequent caudal advancement of the needle. A pressure measurement technique in which correct needle position within the PVS is detected by different pressure values was introduced by Richardson and colleagues17 and an autodetect syringe was used by Mundey and colleagues.18 These techniques rely on more or less indirect methods of identification of...
the PVS, with estimated failure rates of 10.7–15%\textsuperscript{19, 20} and complication rates of \textasciitilde 5%.\textsuperscript{21, 22}

Ultrasound guidance has been successfully introduced for a large spectrum of regional anaesthetic techniques,\textsuperscript{23, 24} and could also be applicable for PVB to provide direct visualization of PVS puncture and the spread of local anaesthetic. Luyet and colleagues\textsuperscript{25} recently showed in a cadaver model that direct visualization of the SCTL is possible via high-resolution ultrasonography. This prospective consecutive case series was designed to describe the lateral PVS by ultrasonography and to evaluate the feasibility of ultrasound-guided PVB via an out-of-plane needle guidance technique.

**Methods**

After institutional ethical committee approval and written informed consent, 20 female patients (ASA I–II) undergoing unilateral breast cancer surgery were included in this prospective observational study. Infections at the site of injection for the PVB, allergy against amino-amide local anaesthetic drugs, or coagulopathies were considered as contraindications.

**Performance of ultrasonographic-guided PVB**

The PVB was performed in the preoperative area with the patient sitting. Monitoring included ECG, pulse oximetry, and non-invasive arterial pressure. I.V. access was established on the contra-lateral side of the surgical procedure and midazolam 2 mg was administered via the i.v. line.

After surgical disinfection of both cervical–thoracic paravertebral areas and protection of the ultrasound probe and cable with a sterile ultrasound probe cover (Safersonic Conti\textsuperscript{TM} 18 x 120 cm, Safersonic Inc., Ybbs, Austria), initial ultrasound investigation of the T3 and T6 paravertebral region at the surgical side was performed. Transportable ultrasound equipment and a 50 mm linear 15-6 MHz probe were used (SonoSite M-Turbo\textsuperscript{TM}, SonoSite Inc., Bothell, WA, USA).

The ultrasound investigation was performed as follows: identification of T3 and T6 spinous processes by decrement from C7 (vertebra prominens), positioning of the ultrasound probe at the spinous process of T3, lateral movement until the transverse process is visible, and oblique movement until the typical double layer of the IIM, the transverse process, and the pleura are visualized in one image (Fig. 1). The image was stored on the internal hard disc of the ultrasound machine for subsequent measurements (see below).

The block was performed after skin infiltration with lidocaine 1% (1 ml). An out-of-plane needle guidance technique with the needle positioned 1 cm caudal to the ultrasound probe was performed as illustrated in Figure 2. A prefilled 22 G 80 mm facette tip needle with a 30 cm injection line (UniPlex Nanoline, Pajunk Inc., Geisingen, Germany) was used. Once the tip of the needle was in a position between the IIM and the pleura, ropivacaine 0.75% (12 ml) was administered over a period of 30 s after negative aspiration. During administration of the local anaesthetic, an anterior displacement of the pleura (downward movement) was observed. The same procedure was repeated at the T6 level. All PVB procedures were performed by one anaesthesiologist (P.M.).

**PVS measurements**

The following measurements were made at the T3 and T6 levels (Fig. 3):

(i) ultrasound appearance of the IIM in per cent visibility from the transverse process in a lateral direction: 1, none (no visibility); 2, poor (< 25% visibility); 3, moderate (26–50% visibility); 4, good (51–75% visibility); 5, excellent (> 75% visibility);

(ii) skin–IIM distance in millimetres at the level of the lateral border of the transverse process (a);

(iii) skin–pleura distance in millimetres at the same level where the skin–IIM distance was measured (b);

(iv) sagittal diameter in millimetres of the PVS (b – a) (c).
In addition to the measurements above, the estimated puncture depth ($d$) was calculated with the assumption of a needle insertion site 10 mm caudal to the ultrasound probe and a position of the tip of the needle in the middle of the PVS:

$$d = \sqrt{10^2 + \left(\frac{a + c}{2}\right)^2}$$

The calculated puncture depth is more precise than the directly measured puncture depth using the 1 cm markers of the needle.

The following correlations of morphometric data (BMI) and PVS measurements were calculated:

- BMI–visibility IIM T3;
- BMI–visibility IIM T6;
- BMI–depth IIM T3;
- BMI–depth IIM T6;
- BMI–depth pleura T3;

The correlation between depth and visibility of the IIM was also calculated at both puncture levels.

The PVB were deemed successful if the subject did not require opioid administration during the entire perioperative period.

**Intra- and postoperative anaesthesia management**

Subjects were transferred from the preoperative area to the operation theatre 10 min after performance of the PVB. In addition to standard monitoring (ECG, pulse oximetry, and non-invasive arterial pressure), bispectral index monitoring (BIS™, Philips Inc., Eindhoven, The Netherlands) was used for measurement of adequate depth of anaesthesia. General anaesthesia was induced with propofol 2–4 mg kg$^{-1}$, and a laryngeal mask was inserted to allow supported or spontaneous ventilation with oxygen/air ($F_{O_2} = 0.3$) and $\text{E}_{CO_2}$ was maintained between 4.7 and 5.4 kPa. A continuous propofol infusion was adjusted according to BIS monitoring with target values between 35 and 50 to provide adequate depth of anaesthesia. Fluid management was performed by administration of lactated Ringer’s solution 5 ml kg$^{-1}$ h$^{-1}$.

Incision was performed 10 min after admittance to the operation theatre. Once surgery was finished, continuous propofol infusion was discontinued and the laryngeal mask was removed. Subjects were transferred to the recovery room for immediate postoperative observation including standard monitoring and 2 h later to the ward. Subjects received acetaminophen 1 g i.v. after admission to the recovery room and 6, 12, and 24 h after surgery. The entire intra- and postoperative procedure was supervised by one anaesthesiologist (E.F.).

**Rescue and emergency management**

A decrease in arterial pressure or heart rate of >30% from initial values was treated with repetitive bolus administration of etilephrine or atropine, respectively. An intraoperative increase in arterial pressure or heart rate of >30% was assessed as insufficient analgesia and treated with repetitive bolus administration of fentanyl 2 μg kg$^{-1}$ until baseline values were achieved.

Postoperative pain was assessed by visual analogue scale (VAS) at 1 h intervals during the first 12 postoperative hours and thereafter by verbal contact. Subjects were treated with piritramide 3 mg if VAS was ≥3 during the first 12 postoperative hours and thereafter if they reported episodes of pain. Nausea and vomiting was treated with ondansetron 8 mg i.v. The study-related postoperative observation ended 24 h after surgery.

**Postoperative observation**

The puncture areas were investigated to detect local infection or haematoma 24 h after performance of the PVB.

**Statistical analysis**

Pearson’s correlation was performed to determine the correlation of BMI with the visibility and depth of the IIM. Data are presented as median (range).

**Results**

Twenty consecutive patients were included in this study; pertinent data are shown in Table 1. The following surgical procedures were performed: excisional biopsy and sentinel

| Table 1: Pertinent subject data. Data are presented as median (range) except n and side |
|------------------|-------------------|
| Patient variable | Patient data      |
| n                | 20                |
| Side (left/right)| 9/11              |
| Age (yr)         | 58 (41, 74)       |
| Weight (kg)      | 66 (46, 105)      |
| Height (cm)      | 163 (157, 174)    |
| BMI (kg m$^{-2}$)| 24.8 (18.4, 36.3) |
lymph node resection \(n = 4\), quadrant resection \(n = 7\), quadrant resection and sentinel lymph node resection \(n = 6\), second look resection \(n = 1\), and ablation and axillary dissection \(n = 2\).

Appropriate ultrasound identification of the spinous and transverse processes, the IIM, and the pleura was possible at both levels (T3 and T6) in all subjects. Thus, correct placement of the tip of the needle was possible in all cases, resulting in successful blocks in all subjects. Puncture depth was calculated as 30 (23–41) mm for the T3 level and 30 (23–48) mm for the T6 level.

All surgical procedures, as described above, were possible with the combination of ultrasound-guided PVB at the T3 and T6 levels and continuous propofol administration during surgery. No patient required opioids intraoperatively or after operation. After performance of the PVB, the mean arterial pressure (MAP) decreased by 25% from initial values (Fig. 4). One patient received atropine 0.5 mg due to intraoperative bradycardia, whereas 12/20 patients received etilephrine 2–5 mg. All episodes of hypotension occurred up to 45 min after performance of the block. We did not detect any episodes of nausea and vomiting in the postoperative period.

Table 2  Ultrasound measurements at the T3 and T6 levels. Values are expressed as median (range). IIM, internal intercostal membrane; PVS, paravertebral space

<table>
<thead>
<tr>
<th>Variable</th>
<th>Ultrasound measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visibility IIM T3</td>
<td>4 (3, 5)</td>
</tr>
<tr>
<td>Depth IIM T3 (mm)</td>
<td>24 (17, 33)</td>
</tr>
<tr>
<td>Visibility IIM T6</td>
<td>4 (2, 5)</td>
</tr>
<tr>
<td>Depth IIM T6 (mm)</td>
<td>25 (18, 45)</td>
</tr>
<tr>
<td>Diameter PVS T3 (mm)</td>
<td>7 (4, 13)</td>
</tr>
<tr>
<td>Diameter PVS T6 (mm)</td>
<td>7 (4, 12)</td>
</tr>
<tr>
<td>Depth pleura T3 (mm)</td>
<td>31 (24, 46)</td>
</tr>
<tr>
<td>Depth pleura T6 (mm)</td>
<td>32 (24, 49)</td>
</tr>
</tbody>
</table>

All episodes of hypotension occurred up to 45 min after performance of the block. We did not detect any episodes of nausea and vomiting in the postoperative period.

Ultrasound measurements of the IIM, PVS, and pleura are illustrated in Table 2. The depths of the IIM and pleura were similar at the T3 and T6 levels. No differences in ultrasound measurements were detected between the T3 and T6 levels. We did not detect positive correlations between the BMI and the depth or visibility of the IIM. Only weak correlations were found between the BMI and the depth of the IIM or pleura (Table 3).

No local infections or haematomata were detected at the puncture sites 24 h after performance of the block.

### Discussion

This consecutive observational study is the first clinical description of a novel approach to ultrasound-guided PVB. We used a lateral approach to the PVS, which is localized between the transverse process, IIM, and pleura. These anatomical structures were easily detectable by high-resolution ultrasound, and an out-of-plane needle guidance technique was applicable for successful performance of PVB.

The clinical use of PVB has a long history. Sellheim of Leipzig described PVB in 1905 for analgesia after abdominal surgery, and Eason and Wyatt introduced PVB in 1979.
into modern clinical practice. During the past two decades, Karmakar, Lönnqvist, and Richardson have significantly contributed to the popularity of PVB. The practical performance of PVB is still based on pure morphometric and indirect methods of identification of the PVS, such as loss-of-resistance, bone contact, and pressure measurement. In order to estimate the site and depth of puncture, formulae such as \((10.2 + 0.12 \times \text{weight in kg})\) and \((21.2 + 0.53 \times \text{weight in kg})\) have been developed. The major drawback of these indirect methods is a more or less unreliable final needle position and subsequent unpredictable site of administration of the local anaesthetic. Despite a number of publications reporting relatively high success and low complication rates of PVB, an evaluation of the exact percentages regarding this issue is problematic and does not reflect routine clinical practice.

Despite a lack of evidence-based outcome data, direct visualization of anatomical structures via ultrasound has been shown to be beneficial for a large number of regional anaesthetic techniques. The PVB is perfectly suitable for ultrasound guidance due to the superficial position of the anatomical landmarks. In order to avoid impaired visibility of the SCTL and pleura, we developed an approach lateral to the transverse process, in which ultrasound visualization of the transverse process, the lateral continuation of the SCTL—which is described as the IIM—and the pleura was possible in all cases.

The lateral approach via landmark-based guidance methods or ultrasound-guided via an in-plane needle guidance technique for the catheter advancement to the thoracic PVS has been described recently. Renees and colleagues recently described an in-plane technique to advance catheters to the PVS via ultrasound. Despite their encouraging results of correct catheter position, data from Luyet and colleagues indicate an unreliable catheter position in the thoracic PVS in cadavers. These results are consistent with our clinical observation of insufficient surgical analgesia after placement of paravertebral catheters. Therefore, we decided to perform two single punctures at the T3 and T6 levels with a total of 24 ml of local anaesthetic. One single puncture at the T4 or T5 level with 20 ml is an alternative to the double-puncture technique but might be associated with an unpredictable cranial spread of local anaesthetic. The number of dermatomes covered by one single injection in the PVS varies from 1 to 10 and therefore analgesia for breast and axilla surgery might be unpredictable after one single puncture.

Recommended volumes of local anaesthetic for PVB vary. Single-site injection of 15–20 ml is reported as equieffective compared with multiple-site injection of 3–4 ml per level. We decided to administer ropivacaine 0.75% (12 ml) at two levels, and the clinical data of surgery without the use of opioids support this management.

We decided to perform PVB with an out-of-plane technique (Fig. 2), our preferred method for superficial regional blocks, which is associated with lower needle penetration depth compared with in-plane needle guidance. The range of the calculated puncture depth was 23–48 mm, where direct visualization of the needle tip is problematic. Once the needle tip penetrates the IIM and the local anaesthetic is administered, spread of local anaesthetic can be confirmed by anterior movement of the pleura (Fig. 5). In addition, patients report a slight feeling of pressure during injection probably due to displacement of the pleura.

We did not perform an additional loss-of-resistance technique because of possible gaps between the lateral and medial portion of the SCTL and the IIM, and the impossibility to detect penetration of the needle through the SCTL or IIM. In addition, we have previously observed that facette tip needles provide almost painless puncture procedures and allow exact placement of the tip of the needle, whereas blunt needles, which are required for a loss-of-resistance technique, are associated with more pain during puncture and less exact needle guidance.

We performed no sensory tests to confirm block quality, which might be interpreted as a limitation. Women undergoing breast cancer surgery are under enormous

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**Fig 5** Ultrasound illustration of the PVS (between the arrows) before (a) and after administration (a) of 12 ml of local anaesthetic.
psychological pressure and data regarding sensory testing immediately before surgery can be unreliable. Nevertheless, all surgical procedures were performed under opioid-free anaesthesia, which provides evidence for successful PVB. In addition, we observed a significant decrease in MAP after blockade due to sufficient sympathetic blockade which might serve as another sign of successful blockade.

Only weak correlations between morphometric data and ultrasound measurements were observed. The IIM is visible by ultrasound independent of the depth or the BMI, which might be advantageous in obese patients. Correlations between BMI and the depth of the SCTL or IIM and the pleura were also weak. Therefore, published formulae calculating the depth of the PVS based on morphometric data should not be used in adults.

In summary, ultrasound-guided PVB, in which local anaesthetic is administered between the transverse process, the IIM, and the pleura via an out-of-plane approach, is an effective regional anaesthetic technique for breast surgery. The lack of correlations between morphometric data and ultrasound measurements of the PVS supports the use of ultrasound guidance for PVB.

**Conflict of interest**
None declared.

**Funding**
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