Standard of Care

All patients enrolled in the study underwent general anesthesia following the standard protocol of University Medical Center Ho Chi Minh City. Preoxygenation was performed before induction. The anesthetic induction regimen included fentanyl 2-3 mcg/kg, propofol 1.5-2.5 mg/kg, and rocuronium 0.6-1.0 mg/kg. After induction, double-lumen endobronchial intubation was performed, and its position was corrected. Anesthesia was maintained with a sevoflurane + air + oxygen mixture, targeting MAC 0.7 – 1.0. Patients also had invasive monitoring devices, including an arterial catheter for continuous blood pressure monitoring, a central venous catheter, and a TOF-watch for neuromuscular blockade monitoring. Active warming was maintained using a forced-air warming blanket set at 37–40°C, ensuring a core temperature of 36–37.3°C. A fluid warmer was also utilized.

During surgery, one-lung ventilation was performed with a tidal volume of 4–6 mL/kg, PEEP of 5–8 cmH_2O, and FiO_2 adjusted to maintain SpO_2 > 92%. Fluid management included Lactated Ringer's solution at a rate of 1.5–2.0 mL/kg/h, not exceeding 6 mL/kg. Urine output was monitored via a urinary catheter, targeting ≥ 0.5 mL/kg/h. Additional fentanyl doses were administered in cases of tachycardia or hypertension >20% above baseline, provided that no significant blood loss had occurred. Hypotension (>20% decrease from baseline or mean arterial pressure <65 mmHg) was managed with either 3–6 mg ephedrine (if heart rate <70 bpm) or 50–100 mcg phenylephrine (if heart rate ≥70 bpm).

At the end of the surgery, endotracheal tube exchange was performed, and neuromuscular blockade was reversed using sugammadex 2 mg/kg when TOF reached 2/4. Postoperative nausea and vomiting (PONV) prophylaxis included dexamethasone 8 mg at induction and ondansetron 4 mg 30 minutes pre-closure, depending on Apfel score. After surgery, all patients were monitored in the post-anesthesia care unit (PACU). Additional analgesia consisted of paracetamol 15 mg/kg every six hours and either ketorolac 30 mg or nefopam 20 mg every eight hours if nonsteroidal anti-inflammatory drugs were contraindicated. Rescue analgesia with morphine (1 mg per dose) was administered when the Visual Analog Scale (VAS) ≥ 4 until pain control was achieved (VAS <4).

Regional Anesthesia Blocks

Following induction, patients were placed in the lateral decubitus position with the operative side facing up. All blocks were performed under ultrasound guidance by experienced anesthesiologists (≥50 procedures each), using strict aseptic techniques. A Logiq Q ultrasound machine with a 10–12 MHz linear probe, an 18G Tuohy needle, and a 20G epidural catheter (B. Braun) were used. The operator identified the T5 vertebral level by ultrasound and marked the site on the skin before sterile draping and block placement.

Erector Spinae Plane Block

The ultrasound probe was initially placed laterally to transect two posterior ribs, then gradually moved medially to identify the transverse process at the T5 level. The transverse process and overlying muscles, including the erector spinae, rhomboid major, and trapezius, were visualized. A Tuohy needle was advanced in-plane to the plane between the transverse process and erector spinae muscle. After hydrodissection with 10 mL saline and confirmation via the “breathing sign”, a catheter was inserted into the T4 level.

Thoracic Paravertebral Block

The T5 spinous process was first identified, and the ultrasound probe was positioned longitudinally in a parasagittal orientation, similar to the erector spinae plane block approach. The probe was moved medially until the transverse process, pleura, and paravertebral space were visualized. Under strict aseptic conditions, an 18G Tuohy needle was inserted in-plane from a caudal-to-cephalad direction, targeting the paravertebral space adjacent to the transverse process. After confirming the correct needle placement by hydrodissection with 10 mL of saline, a 20G catheter was advanced at least 3 cm into the space. The catheter position was further verified by additional saline injection and observation of pleural displacement without intrapleural spread.

In both techniques, the catheter was secured using skin adhesive and Tegaderm. A bolus of 15 mL ropivacaine 0.5% was administered 30 minutes before incision. Postoperatively, a pump containing 200 mL ropivacaine 0.2% delivered programmed autoboluses of 15 mL every six hours. Catheters were maintained until hospital discharge or up to four days after surgery.

Outcomes

Outcomes were assessed at predefined postoperative intervals. The primary outcome was to measure cumulative morphine consumption at 24 and 48 hours after surgery. The secondary outcome was to evaluate pain intensity using the VAS score at rest and during coughing at 1, 2, 6, 12, 24, 48, 72, and 96 hours postoperatively. The tertiary outcomes involved assessing the dermatomal distribution of sensory blockade using the pinprick test 6 and 24 hours after surgery.