Erector spinae plane block for minimally invasive mitral valve surgery: a double-blind, prospective, randomised placebo-controlled trial—a study protocol

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Abstract

Introduction In the context of enhanced recovery after cardiac surgery, surgical techniques for mitral valve surgery have witnessed substantial modifications, from approaching the heart using open approaches with traditional sternotomy to thoracoscopic access via minithoracotomy. After cardiac surgery, acute postoperative pain is frequent and caused by surgical incision and retraction. Perioperative analgesia in cardiac surgery still relies mainly on opioids. Although neuraxial techniques could be a valuable non-opioid-based analgesia regimen, they can be associated with devastating complications in situations with (iatrogenic) coagulation abnormalities. Only two randomised clinical trials describe the erector spinae plane (ESP) block to provide sufficient postoperative analgesia following cardiac surgery with median sternotomy. Regarding postoperative analgesia after cardiac surgery with a minithoracotomy approach, adequately designed trials are still lacking. We, therefore, designed a double-blind, placebo-controlled trial to prove the hypothesis that the ESP block reduces opioid consumption in patients undergoing minimally invasive mitral valve surgery (MIMVS).

Methods and analysis Sixty-four patients undergoing MIMVS will be included in this double-blind, prospective, placebo-controlled trial. Patients will be randomised to receive an ESP block with either intermittent ropivacaine 0.5% (ropi group) or normal saline 0.9% (placebo group). Both groups will receive patient-controlled intravenous analgesia with morphine following extubation. Primary endpoint is the 24-hour cumulative morphine consumption after extubation. Multiple secondary endpoints will be evaluated.

Ethics and dissemination The study is approved by the ethics committee of the University Hospitals Leuven, the Clinical Trials Centre of the University Hospitals Leuven and the ‘Federaal Agentschap voor Geneesmiddelen en Gezondheidsproducten’. Dissemination of the study results will be via scientific papers.

Strengths and limitations of this study

► It is a randomised double-blind, placebo-controlled trial to evaluate the clinical impact of an erector spinae plane (ESP) block.
► The impact of regional anaesthesia in an enhanced recovery after cardiac surgery programme will be evaluated.
► This is the first randomised trial evaluating a unilateral ESP block in cardiac surgery.
► The monocentric design is the main limitation of this study.

Trial registration number EudraCT identifier: 2019-001125-27.
vomiting, confusion and respiratory depression), which can substantially impair the recovery process.\(^3\)

To overcome these shortcomings, more distal nerve blocks have been (re)discovered and implemented, such as the erector spinae plane (ESP) block and the serratus plane block.\(^1\) These blocks are examples of relatively superficial musculofascial plane blocks. The ESP block is placed into the plane between the erector spinae muscles and the posterior aspect of the transverse processes.\(^5\)

The American Society of Regional Anesthesia (ASRA) 2018 guidelines suggest that performing deep peripheral nerve blockades (ie, a neuraxial or paravertebral block) in an anticoagulated patient is unsafe.\(^2\) The determination of safety for superficial blocks ought to account for compressibility, consequences of bleeding and site vascularity.\(^7\) Based on this principle, it has been suggested that for the ESP block, the complication risk due to bleeding is low and is outweighed by the benefit of superior analgesia and concomitant revalidation possibilities.\(^6\)

In cardiac surgery, the ESP block has been described to adequately provide perioperative analgesia in only two randomised controlled trials and several case reports and case series.\(^5\) Based on these clinical reports, analgesia is believed to be achieved by paravertebral and craniocaudal spread of dye. However, there is still debate about whether the local anaesthetic administered also reaches the paravertebral space.\(^12\)–\(^14\) To achieve an extensive spread, the ESP block requires the injection of relatively large volumes of local anaesthetic (approximately 20–30mL) due to the distance between the injection site and the target area.\(^15\) Duration of analgesia after an ESP block remains a matter of controversy, depending on the used mixture and systemic absorption of the local anaesthetics,\(^8\)\(^3\) but can be prolonged with the placement of a catheter.\(^16\) Although limited data is available, the consensus among experts is that the use of intermittent bolus administration of local anaesthetics results in a better spread and analgesia as compared to continuous infusion.\(^17\)

Ropivacaine, a long-acting amide local anaesthetic, is routinely used in musculofascial plane blocks with a proven safety profile.\(^18\) Pre-clinical pharmacological studies show anti-inflammatory effects of ropivacaine; this still needs validation in the clinical setting.\(^16\)

Minimally invasive procedures, such as minimally invasive mitral valve surgery (MIMVS), are often part of an enhanced recovery after cardiac surgery (ERACS) programme, aiming to improve postoperative outcome and reduce the postoperative complication rate.\(^20\) In contrast to conventional sternotomy, thoracotomy can result in an increased incidence of moderate to severe postoperative pain.\(^21\) In these surgeries, musculofascial plane blocks appear to be a valid option to improve postoperative pain and reduce opioid consumption.\(^22\) In our centre, MIMVS is performed via a right-sided minithoracotomy, between the third or fourth intercostal space, with a 4–5 cm periareolar or submammmary incision.

Based on the perceived advantage of a paravertebral spread of the local anaesthetic following an ESP block and the encouraging results of previous ESP studies as mentioned above, we hypothesise that an ESP block with ropivacaine (ropi group) after MIMVS will result in a significant reduction in total postoperative opioid consumption compared with an ESP block with normal saline 0.9% (placebo group). To our knowledge, this study is the first double-blind, placebo-controlled trial to evaluate the clinical impact of a unilateral ESP block in minimally invasive cardiac surgery.

**Primary objective**

This trial will evaluate the efficacy of an ESP block with intermittent boluses of ropivacaine on postoperative pain and recovery compared with normal saline following MIMVS.

**METHODS AND ANALYSIS**

**Trial design**

This single-centre, double-blind, prospective, randomised controlled trial will be performed at the University Hospitals Leuven. The investigator will perform the anaesthesia and perform the ESP block. Following extubation, the investigator will evaluate postoperative pain scores and check the ESP catheter position after 18 hours. Both the investigator and the patient are blinded to the group affiliation. This protocol follows the Standard Protocol Items: Recommendations for Interventional Trials (SPIRIT) guidelines and fulfills the SPIRIT checklist (online supplemental file 1); a SPIRIT checklist is provided in figure 1.

**Randomisation**

All patients will be randomised through a computer-generated permuted block randomisation sequence (variable block size with 1:1 allocation). Enclosing assignments in opaque, sequentially numbered, sealed envelopes will ensure allocation concealment. Envelopes will only be opened at the end of surgery after confirmation of ERACS programme, including postanaesthesia care unit (PACU) admittance. Research personnel will then prepare the trial medications (ropi group: ropivacaine 0.5% or placebo group: normal saline 0.9%). Of note, the trial medications have the same volume, 30mL for the first dose and 20mL for the following three doses, and are identically looking. Syringes will be labelled with the mark ‘trial medication’ so that the investigator will remain blinded.

If, for any cause, a patient is withdrawn from the ERACS programme (eg, due to perioperative complications or for logistic reasons), this will be classified as screening failure. Code break will only be permitted if the patient
shows life-threatening symptoms of local anaesthetic systemic toxicity (LAST) to allow appropriate treatment.

**Anaesthesia and interventional plan**

Our institutional ERACS programme will be used in all patients to standardise perioperative treatment in both groups. This protocol includes (1) avoidance of prolonged fasting (by stimulating the intake of a carbohydrate drink up to 2 hours preoperatively), (2) no premedication, (3) postoperative nausea and vomiting (PONV) and antibiotic prophylaxis, (4) early postoperative removal of drains and catheters (if possible on postoperative day 1), (5) early restart of oral nutrition (at the day of surgery) and (6) early mobilisation of the patient. The study visits are summarised in figure 2.

**Induction and maintenance of anaesthesia**

In general, patient management will be performed according to the below-mentioned institutional standards. However, it is possible that the attending anaesthesiologist changes this management plan to optimise the patients’ care.

Prior to anaesthesia, all patients must be in a fasting state for 6 hours and no premedication is given. After applying a five-lead ECG and pulse oximetry, a peripheral intravenous line (16-gauge cannula) and radial arterial catheter (20-gauge cannula) will be placed. After preoxygenation (fraction of inspired oxygen=1.0), general anaesthesia will be induced with intravenous remifentanil (0.5 µg/kg/min) followed by a bolus of propofol 0.5–1 mg/kg. Tracheal intubation will be facilitated by a bolus administration of rocuronium 1.0 mg/kg. For one-lung ventilation, a left-sided double-lumen endotracheal tube or bronchus blocker will be inserted. Positioning will be checked with fibre-optic bronchoscopy. Standard American Society of Anesthesiologists monitoring will be completed with temperature and capnography measurements. Besides, respiratory and haemodynamic monitoring will be used to facilitate haemodynamic management based on our

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**STUDY PERIOD**

| Timepoint   | Enrolment | Allocation | Post-allocation | Close-out |
|-------------|-----------|------------|-----------------|-----------|
|             | 0         | B₀         | T₀, +0-2h       | B₀, +6h   |
|             |           |            | B₀, +12h        | B₀, +18h  |
|             |           |            | T₀, +24h        | B₀, +30d  |

**ENROLMENT:**
- Eligibility screen
- Informed consent
- Allocation

**INTERVENTIONS:**
- Ropivacaine-group
- Placebo-group

**ASSESSMENTS:**
- Baseline dataset
- Extubation time
- Morphine consumption
- NRS for pain
- Sensory block
- Catheter position
- Adverse events
- Safety endpoints (VARC-2)

**Figure 1** Standard Protocol Items: Recommendations for Interventional Trials. B₀, block placement; d, days; h, hours; NRS, 11-point Numerical Rating Scale; T₀, time of extubation; VARC-2, Valve Academic Research Consortium-2.
institutional routine, including the placement of an invasive arterial and central venous line, and tracheoesophageal echocardiography. Moreover, the Bispectral Index (BIS) will guide the depth of anaesthesia in both groups.

PONV prophylaxis will be achieved with 5mg intravenous dexamethasone and 4mg intravenous ondansetron.

General anaesthesia will be maintained with inspiratory sevoflurane concentrations of 1.5%–2.0%, titrated to achieve a BIS of 40–60. Moreover, patients will receive a continuous infusion of remifentanil (0.1–0.3 µg/kg/min) and adjusted depending on patient’s responses such as spontaneous movements, sweating, eyelash reflex, pupillary size, a sudden increase in heart rate or arterial blood pressure.

The surgical procedure is performed on cardiopulmonary bypass (CPB). Before the initiation of CPB, heparin is administered to achieve an activated clotting time (ACT) of >400s. Prior to the release of the aortic clamp, magnesium sulfate 3g intravenously will be administered. After separating the patient from CPB, protamine is administered for the reversal of heparin in order to achieve the normalisation of the ACT.

Interventional treatment

After completion of the surgery, the patient will be placed in a left lateral decubitus position (on the non-operated hemithorax). A high-frequency linear ultrasound transducer will be positioned 3cm lateral to the T5 spinous process tip in a longitudinal orientation. After identifying three landmark muscles (trapezius, rhomboid major and erector spinae) and the T5 transverse process’s tip, a 75mm Sonolong Sono NanoLine needle (Pajunk, Germany) will be inserted in a cephalad-to-caudal direction as shown in figure 3.

The needle will be positioned on the tip of the T5 transverse process. The needle’s correct position will be confirmed by a linear pattern of fluid spread (20 mL) of trial medication deep to the erector spinae muscle. Subsequently, a catheter will be advanced 5 cm beyond the needle’s tip into the interfascial plane below the erector spinae muscle. A linear pattern of fluid spread will be confirmed by visual confirmation (on ultrasound) of the correct catheter position, the remaining 10 mL of trial medication will be injected through the catheter; this will be defined as block time 0 (B0). After securing the catheter with transparent sterile dressings, the patient will be turned on his back. Further administration of the trial medication will be performed through the catheter every 6 hours, with the last dose being administered 18 hours after the first injection.

Before removing the ESP catheter, visual confirmation, by ultrasound, for correct catheter position and spread will be performed after administering the last trial medication (B0 +18 hours). The correct catheter position is defined as a visualisation of the catheter tip within the interfascial plane below the erector spinae muscle and a linear pattern of fluid spread into this plane.
Postoperative analgesia
Irrespective of group allocation, postoperative analgesia will be provided with a bolus of intravenous morphine (0.1 mg/kg) at the end of surgery and acetaminophen intravenously (15 mg/kg, four times a day). Patients are transferred intubated to the PACU under sedation with dexmedetomidine (0.5 µg/kg/hour) and remifentanil (0.1 µg/kg/min). These infusions will be stopped once the patient is clinically deemed ready for extubation, usually 30–120 min after admission to the PACU. Following extubation (T0), patients will receive a patient-controlled intravenous analgesia (PCIA) pump with morphine, which will be programmed in an on-demand-only mode (morphine bolus of 1.5 mg every 7 min with a maximum of 30 mg every 4 hours). Administration of the trial medication through the ESP catheter at the PACU will be done every 6 hours after the first dose (B0, +6 hours, B1, +12 hours and B2, +18 hours), three times in total.

Following extubation, the severity of pain will be assessed at rest and during coughing using an 11-point Numerical Rating Scale (NRS) for pain (0=no pain, 1–3=presence of pain but no additional treatment necessary, 4–7=moderate to severe pain requiring additional treatment with morphine PCIA and 7–10=severe to worst imaginable pain requiring rescue treatment). In case of severe postoperative pain (NRS for pain ≥7), a clinical bolus (1–2 mg) of morphine will be given to the patient. If the pain is localised at the drain incision site and does not respond to morphine PCIA treatment, an infiltration of 10 mL of ropivacaine 0.5% can be considered. The latter will be classified as treatment failure of the ESP block. Moreover, morphine PCIA is not sufficient to treat ‘pericarditis pain’. The latter is expressed as sharp, stabbing chest pain and is mainly diagnosed based on clinical suspicion and the documentation of new widespread ST segment elevations or PR depression on the ECG. These patients will be treated with acetylsalicylic acid 500 mg intravenously every 8 hours and colchicine 1 mg orally two times per day.

Twenty-four hours postextubation, morphine PCIA will be stopped and data will be extracted from the pump. Further analgesic treatment depends on the protocol used on the ward with acetaminophen (15 mg/kg every 6 hours) and intermittent subcutaneous morphine (0.1 mg/kg).

Patient and public involvement
Patient or members of the public were not involved in the development, recruitment or conduction of this study. After completion of the study, an information letter about the results will be provided for study participants.

Outcomes, measurement and data collection
Primary endpoint
The cumulative 24-hour morphine consumption, after patient’s extubation, will be considered as the primary outcome parameter.

Secondary endpoints
Secondary endpoints include pain intensity evaluated by the NRS for pain, requested dosage of morphine PCIA, additional analgesic requirements (non-opioids), the extent of sensory block (assessed at T0 +2 hours and T0 +18 hours), time to chest drain removal, hospital length of stay and the incidence of adverse events (AE) related to the intervention or surgical procedure. Also, the incidence of other (serious) AE such as the incidence of atrial fibrillation, pleural effusion, pericarditis, LAST and PONV will be recorded. To detect a difference in the inflammatory response, blood samples will be collected at three different time points: at baseline (placement of arterial line), at the end of the surgery and at postoperative day 1 following the last dose through the ESP catheter. From these blood samples, inflammatory parameters (C reactive protein, interleukin (IL)-6 and IL-10) will be examined.

Safety issues
The interventional treatment will be performed under haemodynamic monitoring in a fully equipped operating theatre. The risk of accidental intravenous or intramuscular injection will be minimised by ultrasound guidance and needle aspiration before injection. Patients are
admitted to the PACU following surgery and block placement. A dedicated nurse will follow the patients’ vital signs, and a computer-generated early warning system is continuously monitoring these vital signs.

The ESP block has been shown to be safe in numerous reports, with only two publications reporting a pneumothorax linked to the ESP block. Large doses of local anaesthetics carry the potential risk of LAST and can affect the cardiovascular system (causing arrhythmias and hypotension) and the central nervous system (causing confusion, drowsiness and seizures). However, the doses administered in our study have been repeatedly used in recent studies without any side effects. As a safety measure, patients will be continuously monitored in the PACU with pulse oximetry, ECG and invasive blood pressure until at least 1 hour after the last administration of the trial medication according to the guidelines of the ASRA. In case of symptoms suggesting LAST, code break is allowed to start adequate treatment according to international guidelines.

Also, the inclusion of each patient into the trial is entered in the electronic hospital information system. Hence, this is visible to all physicians and nurses involved in the patients’ care. All AE will be reported immediately to the research coordinator and principal investigator. The latter will report suspected unexpected serious AE to the federal health authorities. Although safety will be evaluated, due to the small sample size, we will not be able to provide firm evidence on the safety of the ESP block in these patients.

Safety endpoints
Early safety endpoints at 30 days as defined by Valve Academic Research Consortium-2 (all-cause mortality, stroke, life-threatening bleeding, acute kidney injury (stage 2 or 3), major vascular complication or valve-related dysfunction) will be evaluated.

Statistical analysis and sample size calculation
Sample size estimation
The present study aims to confirm the efficacy of the proposed treatment defined as an ESP block with ropivacaine 0.5% compared with placebo (normal saline 0.9%).

To have 80% power to show a 25% reduction in the 24-hour morphine consumption in the ropi group versus the placebo group using a two-sided test for a ratio of means (with an alpha=5%), 30 patients per group are needed assuming a coefficient of variation (CV) (SD divided by the mean) equals to 0.40. The assumed CV is a conservative estimate obtained from preliminary own, non-published data on MIVS. To anticipate the loss of study power due to the possibility of dropouts, two extra patients in each group will be included, yielding 32 patients per group.

The CV will be checked in a blinded interim analysis after the inclusion of 32 patients in total. If the CV appears higher than assumed in the sample size calculation, we will increase the number of patients accordingly. If the CV is lower than assumed, the sample size will remain the same.

Statistical data analysis
For the primary outcome, a two-sided t-test for the ratio of means on log-transformed data will be used to compare the 24-hour cumulative morphine intake between both groups. A 95% CI for the ratio of the geometrical means will be reported. A Mann-Whitney U test will test the robustness of the conclusion if the log-transformed data shows a departure from normality based on the Shapiro-Wilk W test statistic. A p value smaller than 0.05 will be considered significant.

As for the secondary endpoints, a linear model for longitudinal measurements (with the selection of the covariance structure based on the Akaike information criterion) will be used for variables that were measured over time (NRS for pain). The number of times morphine PCA is requested will be analysed using a model for count data (Poisson or negative binomial model, depending on the presence of overdispersion). The incidence of LAST will be compared between the groups using Fisher’s exact test. A Mann-Whitney U test will be used for the maximum number of dermatomes, separately at two time points (after the first and the last dose).

The postoperative evolution of the incidence of nausea and vomiting will be evaluated with a logistic regression model with generalised estimating equations. Fisher’s exact test will be used for the comparison of the presence of ‘ever PONV’ during the postoperative follow-up, as well as for each of the early safety endpoints at 30 days (all-cause mortality, stroke (disabling and non-disabling), life-threatening bleeding, acute kidney injury—stage 2 or 3 (including renal replacement therapy), coronary artery obstruction requiring intervention and major vascular complication). A linear model for longitudinal measurements will be used with an unstructured covariance matrix to analyse the inflammatory response. For each serum marker, a separate analysis will be performed. If needed, a transformation of the response will be applied to obtain a normal distribution.

The (co-)investigator or study nurse will review completed case record forms for completeness and correctness before digitalisation and statistical analysis. Case record forms will be completed from data drawn from the source documents and the electronic hospital information system. Data will be coded and analysed in line with the intention-to-treat principle.

Ethics and dissemination
The trial will be carried out in line with the principles of the Declaration of Helsinki, the principles of Good Clinical Practice and following all regulatory requirements. The study, version DH 005—31 May 2019, is approved by the ethics committee of

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Open access

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Recruitment

The principal investigator or co-investigator will recruit all consecutive patients planned for elective MIMVS and being candidates according to the inclusion and exclusion criteria of this study (figure 4). Detailed background information will be given about the study and any issue brought forward by the patient will be answered. Besides, patients will be informed about the possible risk of the

Figure 4  Schematic diagram of the study protocol and sampling process. BMI, body mass index; ERACS, enhanced recovery after cardiac surgery; ESP, erector spinae plane; MIMVS, minimally invasive mitral valve surgery; NRS, 11-point Numerical Rating Scale; PCIA, patient-controlled intravenous analgesia; PONV, postoperative nausea and vomiting.
the current trial is the first placebo-controlled, double-blind, randomised controlled trial for unilateral ESP block in an ERACS programme. We will evaluate the effect of adding an ESP block to a standard postoperative analgesic regimen on postoperative morphine consumption. Furthermore, we will evaluate the presence of a sensory block with a loss of cold sensation.

There are several limitations to our protocol. First, due to the novelty of the ESP block, little is known about optimal dosing regimens. The dosing of ropivacaine used in our trial has been chosen to balance the risk of LAST against the benefit of this regional anaesthetic technique. One could argue to reduce the concentration of ropivacaine from 0.5% to 0.25% or even lesser to increase the volume and/or reduce the dosing interval. We opted to use ropivacaine 0.5% to provide a dense block with adequate analgesic effect. Second, the interval between the boluses could theoretically be reduced. Based on our clinical practice in peripheral nerve blocks and published analgesic duration, we decided to set the interval between each bolus to 6 hours. We will evaluate the timing of analgesic request from the PCA pump and NRS for pain to detect whether the interval between the boluses is adequate.

Trial status
The final protocol version of the current study is DH 005, with the date of this version being 31 May 2019. Patient recruitment was started in July 2019. Enrolment is planned for a period of 24 months. An additional period of 4 months is intended for statistical analysis, manuscript preparation and publication of the study results in an international journal.

REFERENCES
1. Jellish WS, Orfadedeh M. Enhanced recovery after surgery for cardiac surgery: will we have the techniques needed to reduce opioid use and still provide appropriate analgesia? J Cardiothorac Vasc Anesth 2019;33:547–8.
2. Horlocker TT, Vandermeulen E, Kopp SL, et al. Regional anesthesia in the patient receiving antithrombotic or thrombolytic therapy: American Society of regional anesthesia and pain medicine evidence-based guidelines (fourth edition). Reg Anesth Pain Med 2018;43:263–309.
3. Chandrakantant A, Glass PSA. Multimodal therapies for postoperative nausea and vomiting, and pain. Br J Anaesth 2011;107:127–40.
4. Mittnacht AJC, Shariat A, Weiner MM, et al. Regional techniques for cardiac and Cardiac-Related procedures. J Cardiothorac Vasc Anesth 2019;33:532–46.
5. Forero M, Adhikary SD, Lopez H, et al. The erector spinae plane block: a novel analgesic technique in thoracic neuropathic pain. Reg Anesth Pain Med 2016;41:621–7.
6. Adhikary SD, Prasad A, Soleimani B, et al. Continuous erector spinae plane block as an effective anagelics option in anticoagulated patients after left ventricular assist device implantation: a case series. J Cardiothorac Vasc Anesth 2019;33:1063–7.
7. Borys M, Gawęda B, Heroczy B, et al. Erector spinae-plane block as an analgesic alternative in patients undergoing mitral and/or tricuspid valve repair through a right mini-thoracotomy - an observational cohort study. Wideochir Inne Tech Maloinwazyjne 2020;15:208–14.
8. Chin KJ, Malhas L, Perlis A. The erector spinae plane block provides visceral abdominal analgesia in bariatric surgery: a report of 3 cases. Reg Anesth Pain Med 2017;42:372–6.
9. Krishna SN, Chauhan S, Bhoi D, et al. Bilateral erector spinae plane block for acute post-surgical pain in adult cardiac surgical patients: a randomized controlled trial. J Cardiothorac Vasc Anesth 2019;33:368–75.
10. Macaire P, Ho N, Nguyen T, et al. Ultrasound-Guided continuous thoracic erector spinae plane block within an enhanced recovery program is associated with decreased opioid consumption and improved patient postoperative rehabilitation after open cardiac surgery. J Acute Care Surg 2018;33:271–6.
Surgery-A Patient-Matched, controlled before-and-after study. *J Cardiothorac Vasc Anesth* 2019;33:1659–67.

11 Macaire P, Ho N, Nguyen V, et al. Bilateral ultrasound-guided thoracic erector spinae plane blocks using a programmed intermittent bolus improve opioid-sparing postoperative analgesia in pediatric patients after open cardiac surgery: a randomized, double-blind, placebo-controlled trial. *Reg Anesth Pain Med* 2020;45:805–12.

12 Vidal E, Giménez H, Forero M, et al. Erector spinae plane block: a cadaver study to determine its mechanism of action. *Rev Anestesiol Reanim* 2018;65:514–9.

13 Ivanusic J, Konishi Y, Barrington MJ. A cadaveric study investigating the mechanism of action of erector spinae plane blockade. *Reg Anesth Pain Med* 2018;43:567–71.

14 Adhikary SD, Bernard S, Lopez H, et al. Erector spinae plane block versus Retrolaminar block: a magnetic resonance imaging and anatomical study. *Reg Anesth Pain Med* 2018;43:756–62.

15 Choi Y-J, Kwon H-J, O J, Cho T-H, et al. Influence of injectate volume on paravertebral spread in erector spinae plane block: an endoscopic and anatomical evaluation. *PLoS One* 2019;14:e0224487.

16 Tsai BCH, Navarathnam M, Boltz G, et al. Bilateral automated intermittent bolus erector spinae plane analgesic blocks for sternotomy in a cardiac patient who underwent cardiopulmonary bypass: a new era of cardiac regional anesthesia. *J Clin Anesth* 2018;48:9–10.

17 Ilfeld BM. Continuous peripheral nerve blocks: an update of the published evidence and comparison with novel, alternative analgesic modalities. *Anesth Analg* 2017;124:308–35.

18 Eng HC, Ghosh SM, Chin KJ. Practical use of local anesthetics in regional anesthesia. *Curr Opin Anaesthesiol* 2014;27:382–7.

19 Wu L, Li L, Wang F, et al. Anti-Inflammatory effect of local anaesthetic ropivacaine in lipopolysaccharide-stimulated RAW264.7 macrophages. *Pharmacology* 2019;103:228–35.

20 Mkalaluh S, Szczeciwicz M, Dib B, et al. Early and long-term results of minimally invasive mitral valve surgery through a right mini-thoracotomy approach: a retrospective propensity-score matched analysis. *PeerJ* 2018;6:e4810.

21 Ezelsoy M, Oral K, Caynak B, et al. Pain and the quality of life following robotic assisted minimally invasive surgery. *Heart Surg Forum* 2016;19:165–8.

22 Muñoz-Leyva F, Chin KJ, Mendolia WE, et al. Bilateral continuous erector spinae plane (ESP) blockade for perioperative Opioid-Sparing in median sternotomy. *J Cardiothorac Vasc Anesth* 2019;33:698–703.

23 Adler Y, Charron P, Imazio M, et al. 2015 ESC Guidelines for the diagnosis and management of pericardial diseases: The Task Force for the Diagnosis and Management of Pericardial Diseases of the European Society of Cardiology (ESC). *Endorsed by: The European Association for Cardio-Thoracic Surgery (EACTS). Eur Heart J* 2015;36:2921–64.

24 Sondekoppam RV, Tsui BCH. “Minimally invasive” regional anesthesia and the expanding use of interfascial plane blocks: the need for more systematic evaluation. *Can J Anaesth* 2019;66:855–63.

25 Adhikary SD, Pruett A, Forero M, et al. Erector spinae plane block as an alternative to epidural analgesia for post-operative analgesia following video-assisted thoracoscopic surgery: a case study and a literature review on the spread of local anaesthetic in the erector spinae plane. *Indian J Anaesth* 2018;62:75–8.

26 Bleckner L, Solla C, Fileta BB, et al. Serum free ropivacaine concentrations in patients receiving continuous peripheral nerve block catheters: is it safe for long-term infusions? *Anesth Analg* 2014;118:225–9.

27 McEvoy MD, Thies K-C, Elain S, et al. Cardiac arrest in the operating room: part 2-Special situations in the perioperative period. *Anesth Analg* 2018;126:899–903.

28 Kappetein AP, Head SJ, Généreux P, et al. Updated standardized endpoint definitions for transcatheter aortic valve implantation: the valve academic research Consortium-2 consensus document. *J Thorac Cardiovasc Surg* 2013;145:6–23.

29 Kieser M, Friede T. Simple procedures for blinded sample size adjustment that do not affect the type I error rate. *Stat Med* 2003;22:3571–81.
# Reporting checklist for protocol of a clinical trial.

Based on the SPIRIT guidelines.

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| Reporting Item                              | Page Number |
|---------------------------------------------|-------------|
| **Administrative information**              |             |
| Title                                       | #1          |
| Descriptive title identifying the study design, population, interventions, and, if applicable, trial acronym | 1           |
| Trial registration                          | #2a         |
| Trial identifier and registry name. If not yet registered, name of intended registry | 3 & 18-19   |
| Trial registration: data set                | #2b         |
| All items from the World Health Organization Trial Registration Data Set | 4-6         |
| Protocol version                            | #3          |
| Date and version identifier                 | 6           |
| Funding                                     | #4          |
| Sources and types of financial, material, and other support | 22          |
| Roles and responsibilities: contributorship | #5a | Names, affiliations, and roles of protocol contributors | 1 & 22 |
| Roles and responsibilities: sponsor contact information | #5b | Name and contact information for the trial sponsor | 4 |
| Roles and responsibilities: sponsor and funder | #5c | Role of study sponsor and funders, if any, in study design; collection, management, analysis, and interpretation of data; writing of the report; and the decision to submit the report for publication, including whether they will have ultimate authority over any of these activities | 22 |
| Roles and responsibilities: committees | #5d | Composition, roles, and responsibilities of the coordinating centre, steering committee, endpoint adjudication committee, data management team, and other individuals or groups overseeing the trial, if applicable (see Item 21a for data monitoring committee) | na |

**Introduction**

| Background and rationale | #6a | Description of research question and justification for undertaking the trial, including summary of relevant studies (published and unpublished) examining benefits and harms for each intervention | 7-9 |
| Background and rationale: choice of comparators | #6b | Explanation for choice of comparators | 9 |

**Objectives**

| #7 | Specific objectives or hypotheses | 9 |

**Trial design**

| #8 | Description of trial design including type of trial (eg, parallel group, crossover, factorial, single group), allocation ratio, and framework (eg, superiority, equivalence, non-inferiority, exploratory) | 10 |
### Methods:
#### Participants, interventions, and outcomes

| Description                                                                                      | Page |
|-----------------------------------------------------------------------------------------------|------|
| **Study setting** #9 Description of study settings (eg, community clinic, academic hospital) and list of countries where data will be collected. Reference to where list of study sites can be obtained | 10   |
| **Eligibility criteria** #10 Inclusion and exclusion criteria for participants. If applicable, eligibility criteria for study centres and individuals who will perform the interventions (eg, surgeons, psychotherapists) | 19   |
| **Interventions:** #11a Interventions for each group with sufficient detail to allow replication, including how and when they will be administered | 11-14|
| **Interventions:** #11b Criteria for discontinuing or modifying allocated interventions for a given trial participant (eg, drug dose change in response to harms, participant request, or improving / worsening disease) | 10, 15-16|
| **Interventions:** #11c Strategies to improve adherence to intervention protocols, and any procedures for monitoring adherence (eg, drug tablet return; laboratory tests) | 13-14|
| **Interventions:** #11d Relevant concomitant care and interventions that are permitted or prohibited during the trial | 13-14|
| **Outcomes** #12 Primary, secondary, and other outcomes, including the specific measurement variable (eg, systolic blood pressure), analysis metric (eg, change from baseline, final value, time to event), method of aggregation (eg, median, proportion), and time point for each outcome. Explanation of the clinical relevance of chosen efficacy and harm outcomes is strongly recommended | 15-16|
| **Participant timeline** #13 Time schedule of enrolment, interventions (including any run-ins and washouts), assessments, and visits for | 10   |

**Figure 4**

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participants. A schematic diagram is highly recommended (see Figure).

### Sample size

Estimated number of participants needed to achieve study objectives and how it was determined, including clinical and statistical assumptions supporting any sample size calculations.  16-17

### Recruitment

Strategies for achieving adequate participant enrolment to reach target sample size.  19

### Methods:

#### Assignment of interventions (for controlled trials)

1. **Allocation: sequence generation**  #16a
   Method of generating the allocation sequence (eg, computer-generated random numbers), and list of any factors for stratification. To reduce predictability of a random sequence, details of any planned restriction (eg, blocking) should be provided in a separate document that is unavailable to those who enrol participants or assign interventions.  10

2. **Allocation concealment mechanism**  #16b
   Mechanism of implementing the allocation sequence (eg, central telephone; sequentially numbered, opaque, sealed envelopes), describing any steps to conceal the sequence until interventions are assigned.  10

3. **Allocation: implementation**  #16c
   Who will generate the allocation sequence, who will enrol participants, and who will assign participants to interventions.  10

4. **Blinding (masking)**  #17a
   Who will be blinded after assignment to interventions (eg, trial participants, care providers, outcome assessors, data analysts), and how.  10

5. **Blinding (masking): emergency unblinding**  #17b
   If blinded, circumstances under which unblinding is permissible, and procedure for revealing a participant’s allocated intervention during the trial.  16
Methods: Data collection, management, and analysis

Data collection plan  **#18a**  Plans for assessment and collection of outcome, baseline, and other trial data, including any related processes to promote data quality (e.g., duplicate measurements, training of assessors) and a description of study instruments (e.g., questionnaires, laboratory tests) along with their reliability and validity, if known. Reference to where data collection forms can be found, if not in the protocol

Data collection plan: retention  **#18b**  Plans to promote participant retention and complete follow-up, including list of any outcome data to be collected for participants who discontinue or deviate from intervention protocols

Data management  **#19**  Plans for data entry, coding, security, and storage, including any related processes to promote data quality (e.g., double data entry; range checks for data values). Reference to where details of data management procedures can be found, if not in the protocol

Statistics: outcomes  **#20a**  Statistical methods for analysing primary and secondary outcomes. Reference to where other details of the statistical analysis plan can be found, if not in the protocol

Statistics: additional analyses  **#20b**  Methods for any additional analyses (e.g., subgroup and adjusted analyses)

Statistics: analysis population and missing data  **#20c**  Definition of analysis population relating to protocol non-adherence (e.g., as randomised analysis), and any statistical methods to handle missing data (e.g., multiple imputation)

Methods: Monitoring
| Item | Description |
|------|-------------|
| **Data monitoring:** |  |
| #21a | Composition of data monitoring committee (DMC); summary of its role and reporting structure; statement of whether it is independent from the sponsor and competing interests; and reference to where further details about its charter can be found, if not in the protocol. Alternatively, an explanation of why a DMC is not needed. |
| #21b | Description of any interim analyses and stopping guidelines, including who will have access to these interim results and make the final decision to terminate the trial. |
| **Harms** |  |
| #22 | Plans for collecting, assessing, reporting, and managing solicited and spontaneously reported adverse events and other unintended effects of trial interventions or trial conduct. |
| **Auditing** |  |
| #23 | Frequency and procedures for auditing trial conduct, if any, and whether the process will be independent from investigators and the sponsor. |
| **Ethics and dissemination** |  |
| #24 | Plans for seeking research ethics committee / institutional review board (REC / IRB) approval. |
| #25 | Plans for communicating important protocol modifications (eg, changes to eligibility criteria, outcomes, analyses) to relevant parties (eg, investigators, REC / IRBs, trial participants, trial registries, journals, regulators). |
| #26a | Who will obtain informed consent or assent from potential trial participants or authorised surrogates, and how (see Item 32). |
| #26b | Additional consent provisions for collection and use of participant data and biological specimens in ancillary studies, if applicable. |
| Section                          | #  | Description                                                                                                                                 |
|---------------------------------|----|---------------------------------------------------------------------------------------------------------------------------------------------|
| Confidentiality                 | #27| How personal information about potential and enrolled participants will be collected, shared, and maintained in order to protect confidentiality before, during, and after the trial |
| Declaration of interests        | #28| Financial and other competing interests for principal investigators for the overall trial and each study site                                  |
| Data access                     | #29| Statement of who will have access to the final trial dataset, and disclosure of contractual agreements that limit such access for investigators |
| Ancillary and post trial care   | #30| Provisions, if any, for ancillary and post-trial care, and for compensation to those who suffer harm from trial participation                |
| Dissemination policy:           | #31a| Plans for investigators and sponsor to communicate trial results to participants, healthcare professionals, the public, and other relevant groups (eg, via publication, reporting in results databases, or other data sharing arrangements), including any publication restrictions |
| Dissemination policy:           | #31b| Authorship eligibility guidelines and any intended use of professional writers                                                              |
| Dissemination policy:           | #31c| Plans, if any, for granting public access to the full protocol, participant-level dataset, and statistical code                                |
| Appendices                      |    |                                                                                                                                           |
| Informed consent materials      | #32| Model consent form and other related documentation given to participants and authorised surrogates                                          |
| Biological specimens            | #33| Plans for collection, laboratory evaluation, and storage of biological specimens for genetic or molecular analysis in the current trial and for future use in ancillary studies, if applicable |
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