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Epidural Analgesia in Open Thoraco-abdominal Aortic Aneurysm Repair

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WHAT THIS PAPER ADDS

Thoracic epidural analgesia is effective in reducing post-operative pain with no effect on major post-operative complications. The use of thoracic epidural analgesia, if not contraindicated, might be considered in clinical practice in open thoraco-abdominal aortic aneurysm repair, as it could improve peri-operative management and promote recovery.

Objective: Epidural analgesia improves pain control and outcomes of abdominal aortic aneurysm procedures, while the effect of thoracic epidural analgesia on thoraco-abdominal aortic aneurysm (TAAA) repair is unknown. The aim of the study was to evaluate thoracic epidural analgesia effects in patients undergoing open TAAA repair in terms of pain control and clinically relevant outcomes.

Methods: This was a retrospective study of a prospectively collected database. Patients undergoing open TAAA repair between January 2009 and December 2016.

Results: Four hundred and fifty-nine consecutive patients were included. Thoracic epidural analgesia was used in 409 (89%) of cases. On multivariable analysis, patients who received thoracic epidural analgesia experienced reduced post-operative pain (odds ratio [OR] 0.003, 95% confidence interval [CI] 0.0007–0.009; $p < .001$), a lower rate of acute kidney injury (AKI; OR 0.39, 95% CI 0.21–0.71 [$p = .002$]), atrial fibrillation (OR 0.47, 95% CI 0.23–0.95; $p = .04$), acute myocardial infarction (AMI; OR 0.189, 95% CI 0.05–0.64; $p = .008$), and paraplegia (OR 0.31, 95% CI 0.157–0.615; $p = .001$) compared with the conventional analgesia (CA) group. After propensity score matching, 43 patients in the CA group were compared with 43 in thoracic epidural analgesia group. On case match analysis thoracic epidural analgesia showed a significant reduction in post-operative pain ($p < .001$) and no differences in the incidence of AKI, atrial fibrillation, AMI, and paraplegia. In the thoracic epidural analgesia group there were no epidural haematomas.

Conclusion: Thoracic epidural analgesia was effective in reducing post-operative pain with no effect on major post-operative complications. The use of thoracic epidural analgesia, if not contraindicated, might be considered in clinical practice, even in patients undergoing open TAAA repair. Whether a better post-operative management enhances patient's recovery in this setting remains to be tested.

Keywords: Analgesia, Thoracic epidural analgesia, Thoraco-abdominal aortic aneurysm
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INTRODUCTION

Open thoraco-abdominal aortic aneurysm (TAAA) repair is one of the most difficult and demanding cardiovascular operation for both anaesthesists and surgeons.[1–3]

Post-operative pain is important and may impair post-operative respiratory performance and delay patient mobilisation.

Although epidural analgesia (EA) is the cornerstone of the treatment of post-operative pain after major surgery,[4] scientific evidence from studies performed in patients undergoing open TAAA repair is still lacking. Therefore, it is still not widely employed in this setting, probably owing to the risks of epidural haematoma in patients who need systemic heparinisation and who are at high risk of developing peri-operative coagulopathy secondary to massive bleeding.[3]

In addition, thoracic epidural anaesthesia may alter early post-operative neurological evaluation, in a setting in which neurological complications, mainly paraplegia, the most dreaded event, warrant prompt diagnosis and immediate treatment.

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EA also improved outcomes after major surgery,[4,5] including open abdominal aortic aneurysm (AAA) repair.[6] Compared to AAA repairs, TAAA surgery is a longer and more complex intervention, with a higher risk of complications due to major involvement of the cardiovascular and pulmonary systems. Left thoracotomy is associated with both greater pain and pulmonary complications than AAA. Thus, good post-operative pain control may promote recovery, affecting patient comfort and outcome.

The aim of this study was to analyse the effect of peri-operative thoracic EA in patients undergoing open TAAA repair on pain control and early major post-operative complications.

MATERIALS AND METHODS

Data were collected on consecutive adult patients who underwent elective or urgent open TAAA repair between January 2009 and December 2016 at San Raffaele Scientific Institute. All patients provided signed informed consent allowing for scientific data management; ethical committee approval was waived according to Italian law.

Peri-operative clinical management of patients undergoing TAAA surgery followed the standardised institutional protocol. An adequate multi-organ function assessment was routinely performed to determine the best operative strategy for each patient.

Thoracic EA was performed in all patients, in the absence of contraindications and following the institutional protocol for peri-operative analgesia.[7–9] Reasons to avoid EA were ongoing double platelet medication; clopidogrel discontinuation for $<$7 days; activated partial thromboplastin ratio above 1.3; international normalised ratio $>$1.5; platelet count $<$100,000/mL; severe skeletal deformity; previous cervical and upper thoracic spine surgery; infection at the proposed epidural site; and failure to insert the epidural catheter after three attempts. Aspirin was not considered a contraindication.

The epidural catheter was inserted via a midline approach. After local anaesthesia with 5 mL 2% lidocaine at the most prominent intervertebral space between T6 and T8 (T10 for type 4 and 5 TAAA), an 18 G Tuohy epidural needle was inserted and the epidural space was identified by the loss of resistance to air technique. The catheter was advanced 4–5 cm into the epidural space. After a negative aspiration test, a 2 mL test dose of 2% lidocaine was given. A bloody tap during epidural catheter insertion was managed by first flushing the catheter with sterile saline and then changing the epidural space in the event of further aspiration of blood from the catheter. After three attempts insertion of the epidural catheter was abandoned.

A left double lumen endotracheal tube was used, as one lung ventilation was performed during some steps of the surgery.

Mannitol (0.3 g/kg) and methylprednisolone (30 mg/kg) were administered just before surgery.

If not contraindicated, in patients undergoing types I, II, and III TAAAs, cerebrospinal fluid drainage (CSFD) was applied after the induction of general anaesthesia (GA) in order to decrease patient discomfort. Liquoguard® (Möller Medical GmbH, Fulda, Germany) or Becker External Drainage System were used to manage CSFD and simultaneously measure cerebrospinal fluid pressure. Target cerebrospinal fluid pressure was set to 10 cmH_2O, with draining set to a maximum rate of 20 mL/h.

A bolus of 100 U/kg of intravenous heparin was administered to obtain a target activated partial thromboplastin time around 250 s at least 60 min after epidural catheter insertion. In most cases, left heart bypass was performed, with renal perfusion with cold (4 °C) crystalloid solution or Custodiol® (Dr Franz-Kohler Chemie GmbH, Bensheim, Germany) starting at the time of renal artery isolation and continuing until the renal arteries were re-implanted. Selective perfusion of the visceral arteries with normothermic blood was also started and continued until circulation was restored. The intercostal arteries were re-implanted whenever possible.

After the end of surgery patients were maintained sedated, intubated, and transferred to the intensive care unit (ICU). Weaning from mechanical ventilation was started when the previously validated weaning criteria were met.[10]

An EA continuous infusion was started in the ICU, in the absence of signs of any sensory or motor deficit. Post-operative analgesia was administered by a bolus dose of 0.1–0.2 mL/kg of 2% lidocaine via the epidural catheter, followed by a continuous infusion of 0.2% ropivacaine and 1 μg/mL sufentanil at a rate between 2 and 6 mL/h, according to the authors' departmental protocol.

For cases of paraplegia, the epidural infusion was immediately discontinued to assess the neurological status.

In the CA group, patient controlled analgesia (PCA) with morphine was instituted for post-operative analgesia.[11] All patients in both groups received 1 g paracetamol every 6–8 h (3–4 doses daily).

The epidural catheter was left in place until at least the third day after surgery. For patients on an intravenous unfractionated heparin infusion, the therapy was discontinued $>$6 h before catheter removal and restarted $>$1 h later. Platelet count below 100,000/mL was considered a contraindication to catheter removal.

In patients receiving low molecular weight heparin therapy, no dosage was given for $\geq$12 h before and after epidural catheter removal. The same precautions were taken for CSFD; furthermore, patients were asked to lie in bed for at least 2 h after CSFD removal. Aspirin therapy was not considered a contraindication to epidural catheter removal. Epidural bleeding was assessed clinically; for those suspected of haematoma or evidence of paraplegia, magnetic resonance imaging was performed to distinguish between spinal cord ischaemia or peridural haematoma. All patients received intravenous analgesics on the top of EA as required. A visual analogue scale (VAS) from 0 to 10 was used to verify patients' pain (0 = "no pain at all" up to 10 "pain as bad as could be"). VAS was measured on the first day after surgery on top of epidural anaesthesia and intravenous analgesics, administered according to the

institutional protocol and patient needs. The worst VAS on the first day after surgery was recorded and included in the analysis. Regarding patients who died, VAS evaluation was not included in the analysis in order to avoid an unreliable assessment of analgesia associated with either sedation or an altered neurological status.

Sample size calculation

Based on data from previous studies conducted on patients undergoing major aortic surgery,[11,12] it was estimated that 65% of patients undergoing conventional analgesia (CA) had a VAS score $>$ 5 (primary outcome) vs. only 45% of patients undergoing thoracic epidural anaesthesia. Thus, assuming a type I error of 0.05 and a type II error of 0.2, the authors calculated that 46 patients per group needed to be recruited (STATA version 13; StataCorp, College Station, TX, USA).

Endpoints

The primary endpoint of the study was efficacy of thoracic epidural anaesthesia in patients undergoing open TAAA repair, evaluated with a visual analogue scale (VAS) scale.

Secondary endpoints included in hospital mortality, occurrence of atrial fibrillation, acute kidney injury (AKI; defined according to kidney disease improving global outcomes [KDIGO] criteria, based on both serum creatinine and urine output),[13] need for renal replacement therapy, pulmonary complications (defined as evidence of post-operative pneumonia, pneumothorax, or atelectasis on Xray with impairment in gas exchange), need for non-invasive ventilation, acute ST elevation myocardial infarction, paraplegia, bowel ischaemia, and the occurrence of any complication.

Statistical methods

Statistical analyses were performed using STATA version 13. The chi-square and unpaired, two tailed *t* test or Mann Whitney U test were used to compare proportions and means or medians, respectively. Dichotomous and categorical variables are expressed as *n* (%), while continuous variables are expressed as mean $\pm$ SD in case of normal distribution, or median and interquartile range (IQR) in case of non-normal distribution. VAS values are reported both as absolute values (range 0–10) and as a dichotomous variable, either $<$5 or $\geq$5, with 5 being the threshold between a lesser degree of pain (lower part of the scale) and a greater degree of pain (higher part of the scale). Patients were divided into two groups according to type of analgesia (thoracic epidural anaesthesia: GA vs. CA), and rates of post-operative complications were compared between the two groups.

Multivariable logistic regression was used to analyse associations between analgesia type and complications/adverse events and mortality; the treatment variable (epidural) and baseline variables with a p value $<$ .05 on univariable analysis, were inserted in a stepwise model with a cut off of 0.1. For the missing values a listwise deletion approach was applied.

Moreover, in order to allow an unbiased comparison between patients who received thoracic epidural anaesthesia and patients who did not, a 1:1 propensity score match analysis was carried out. The matching macro presented here is performed 1:1 with a greedy algorithm; a set of cases is matched to a set of controls. The propensity score assessed the odds of receiving thoracic epidural anaesthesia, taking into account both pre-operative and intra-operative potentially confounding variables.

The propensity score was estimated with multivariable logistic regression for thoracic epidural anaesthesia treatment probability including the most relevant pre- and intra-operative variables potentially associated with thoracic epidural anaesthesia and the primary endpoint. To derive the propensity score, a logistic regression model with the following variables was run: age, sex, weight, height, diabetes, kidney disease outcomes quality initiative (KDOQI) Stage 0, KDOQI Stage 3b, coronary artery disease, arrhythmia, previous major non-aortic vascular surgery, previous aortic surgery, Marfan syndrome, pre-operative haemoglobin, partial thromboplastin time, platelet inhibitor therapy, oral anticoagulation, elective surgery, surgical time hour. Baseline and post-propensity score matching balance between covariables were assessed by means of standardised mean differences, and a standardised mean difference $<\pm$ 0.10 was considered as good adjustment between groups.[14] A p value $\leq$ .05 was considered statistically significant.

RESULTS

In total, 459 patients underwent Open TAAA repair during the study period, of whom 409 (89%) received thoracic epidural anaesthesia.

Pre- and intra-operative patient data are given in Tables 1 and 2, respectively. Differences between CA and thoracic epidural anaesthesia patients were noted on the following baseline data: non-insulin dependent diabetes mellitus (0% vs. 8%; p = .04), chronic kidney disease (42% vs. 25%; p = .008), history of arrhythmia (20% vs. 8%; p = .002), previous major non-aortic vascular surgery (46% vs. 28%; p = .01), previous aortic surgery (54% vs. 33%; p = .001), and Marfan syndrome (14% vs. 2.7%; p $<$ .001).

The epidural catheter was not placed in 25 patients (50%) owing to an alteration in coagulation parameters or no discontinuation of antiplatelet therapy, in five (10%) cases owing to a platelet count $<$100,000/dL, in five (10%) owing to the non-elective nature of the procedure, in five (10%) owing to neurosurgical contraindications, in five (10%) owing to patient refusal, and in five cases (10%) owing to placement failure.

Univariable analysis of outcomes is shown in Table 3. Patients in the thoracic epidural anaesthesia group vs. CA controls experienced reduced post-operative pain (VAS 2 [IQR 2–3] vs. 6 [IQR 5–7]; p $<$ .001), lower rate of re-operation for bleeding (2% vs. 10%; p = .002), and mortality (5% vs. 18%; p $<$ .001). Similarly, ICU stay was shorter in thoracic epidural anaesthesia patients (22 h vs. 36 h; p = 0.02). No epidural haematoma was observed in either of the groups. No bloody taps were recorded.

Table 1. Univariable analysis of pre-operative data for the whole population

Variable	Conventional analgesia (n = 50)		Thoracic epidural anaesthesia (n = 409)		p
	n (%) *or* ± mean SD	Missing values	n (%) *or* ± mean SD	Missing values	
Age, years	63 ± 14	0 (0)	66 ± 10	0 (0)	.09
Female gender	6 (12)	0 (0)	117 (29)	0 (0)	.01
Weight, kg	78 ± 14	1 (2)	73 ± 14	6 (1.5)	.03
Height, cm	173 ± 10	1 (2)	169 ± 9	6 (1.5)	.01
Body mass index, kg/m^2	26 ± 5	1 (2)	26 ± 4	6 (1.5)	.3
Arterial hypertension	34 (68)	0 (0)	309 (76)	1 (0.2)	.2
Diabetes	0 (0)	0 (0)	31 (8)	1 (0.2)	.04
Smoking	20 (40)	0 (0)	180 (44)	1 (0.2)	.6
Dyslipidaemia	11 (22)	0 (0)	105 (26)	1 (0.2)	.6
Chronic obstructive pulmonary disease	8 (16)	0 (0)	66 (16)	1 (0.2)	.9
KDOQI stage		0 (0)		1 (0.2)	.03
0	29 (58)		308 (75)		
2	8 (16)		42 (10)		
3A	3 (6)		26 (6)		
3B	7 (14)		20 (5)		
4	3 (6)		9 (2)		
5	0 (0)		3 (1)		
Creatinin, mg/dL	1.16 ± 0.51	0 (0)	1.06 ± 0.58	0 (0)	.2
Glomerular filtration rate, mL/h	75.8 ± 30.5	1 (2)	79.8 ± 25.2	6 (1.5)	.3
History of myocardial infarction	3 (6)	1 (2)	29 (7)	1 (0.2)	.9
Previous coronary revascularisation	10 (20)	0 (0)	52 (13)	1 (0.2)	.2
Arrhythmia	10 (20)	0 (0)	29 (7)	1 (0.2)	.002
Previous major non-aortic vascular surgery	23 (46)	0 (0)	116 (28)	0 (0)	.01
Previous aortic surgery	28 (56)	0 (0)	134 (33)	1 (0.2)	.001
Previous cardiac surgery	11 (22)	0 (0)	62 (15)	4 (1)	.2
Previous stroke	1 (2)	0 (0)	14 (3)	0 (0)	.9
Marfan syndrome	7 (14)	0 (0)	11 (3)	2 (5)	< .001
Thoraco-abdominal aortic aneurysm type		0 (0)		6 (1.5)	.8
1	13 (26)		86 (21)		
2	13 (26)		121 (30)		
3	12 (24)		104 (25)		
4	12 (24)		82 (20)		
5	0 (0)		10 (2)		

SD = standard deviation; KDOQI = kidney disease outcomes quality initiative.

In the multivariable analysis (see Table 4), patients who received thoracic epidural anaesthesia had significantly lower VAS scores (OR 0.003, 95% CI 0.0007—0.009; $p < .001$), AKI (OR 0.39, 95% CI 0.21—0.71; $p = .002$), atrial fibrillation (OR 0.47, 95% CI 0.23—0.95; $p = .04$), acute myocardial infarction (AMI; OR 0.189, 95% CI 0.05—0.64; $p = .008$), and paraplegia (OR 0.31, 95% CI 0.157—0.615; $p = .001$) compared with the control group.

Propensity matching identified a population of 86 patients: 43 treated with thoracic epidural anaesthesia and 43 with PCA.

Patients who received thoracic epidural anaesthesia experienced less post-operative pain than CA controls on univariable analysis (VAS 2 [IQR 2—3] vs. 6 [IQR 5—7]; $p < .001$) (Table 5 and Fig. 1), even in the propensity matched population.

DISCUSSION

The main result of this large, single centre, propensity matched study is that thoracic epidural anaesthesia in patients undergoing open TAAA repair is effective in decreasing post-operative pain vs. CA ($p < .001$), in line with existing literature concerning major surgery.[15]

This is extremely relevant, as several authors have underlined that good pain control should have an important effect on patient outcomes.[15,16]

Whether the well known effects ascribed to epidural anaesthesia will make a difference in the outcome of vascular surgery patients remains an unresolved issue.

The huge number and relevance of potential concomitant elements typical of this high risk surgery may affect outcomes and mask the potential benefits of thoracic epidural anaesthesia itself. In the present study, the data from multivariable analysis have shown a lower incidence of atrial fibrillation and peri-operative AMI in patients treated with thoracic epidural anaesthesia, arguably owing to the inhibition of the sympathetic nervous system. Such results, however, could not be confirmed in the propensity matched population analysis, probably owing to the reduced number of patients included. Furthermore, a higher risk of atrial fibrillation was observed in patients undergoing elective surgery in the multivariable analysis

Table 2. Univariable analysis of intra-operative data for the whole population

Variable	Conventional analgesia (n = 50)		Thoracic epidural anaesthesia (n = 409)		p
	n (%) *or* ± mean SD	Missing values	n (%) *or* ± mean SD	Missing values	
Urgent surgery	9 (18)	0 (0)	34 (8.3)	1 (0.2)	.027
Use of left heart bypass (LHBP)	32 (64)	1 (2)	309 (76)	1 (0.2)	.1
LHBP, min	59 ± 29	1 (2)	58 ± 23	1 (0.2)	.9
Aortic clamping, min	52 ± 25	19 (38)	53 ± 23	105 (26)	.8
Heparin dose, IU	3954 ± 2749	6 (12)	3377 ± 1156	50 (12)	.01
Surgical time, h	5.1 ± 1.8	0 (0)	4.8 ± 1.2	4 (1)	.09
Inotropes	18 (36)	0 (0)	138 (34)	0 (0)	.8

LHBP = left heart bypass; SD = standard deviation; IU = international units.

Table 3. Univariable analysis of outcome data for the whole population

Variable	Conventional analgesia (n = 50)		Thoracic epidural anaesthesia (n = 409)		p
	n (%) *or* ± median (IQR)	Missing values	n (%) *or* ± median (IQR)	Missing values	
Median VAS scale	6 (5–7)	0 (0)	2 (2–3)	0 (0)	< .001
VAS scale ≥ 5	38 (93)	0 (0)	10 (2.3)	0 (0)	< .001
Intensive care unit (ICU) stay, h	36 (20.3–86)	1 (2)	22 (19–46)	4 (1)	.03
Hospital stay, d	9 (7–12)	0 (0)	8 (7–11)	1 (0.2)	.4
ICU re-admission	1 (2)	0 (0)	10 (2.4)	0 (0)	.9
Mechanical ventilation, h	15 (5–20)	0 (0)	15 (8–18)	4 (1)	.9
Mechanical ventilation > 48 h	8 (16)	1 (2)	40 (9.8)	1 (0.2)	.2
Need for tracheal re-intubation	5 (10)	1 (2)	22 (5.4)	0 (0)	.2
Tracheostomy	1 (2)	1 (2)	15 (3.7)	1 (0.2)	.9
Pneumonia	4 (8)	1 (2)	20 (4.9)	0 (0)	.3
Non-invasive mechanical ventilation	19 (38)	1 (2)	152 (37)	3 (0.7)	.9
Acute kidney injury (KDIGO stage)		1 (2)		3 (0.7)	.5
0	21 (43)		211 (52)		
1	16 (33)		97 (24)		
2	8 (16)		57 (14)		
3	4 (8.2)		41 (10)		
Renal replacement therapy	1 (2.0)	1 (2)	18 (4.4)	0 (0)	.7
Atrial fibrillation	7 (14)	1 (2)	53 (13)	1 (0.2)	.8
Peri-operative acute myocardial infarction	2 (4.0)	0 (0)	7 (1.7)	1 (0.2)	.3
Re-operation for bleeding	5 (10)	2 (4)	8 (2.1)	29 (7)	.002
Bowel ischaemia	0 (0.0)	1 (2)	7 (1.7)	1 (0.2)	.9
Paraplegia	5 (10)	0 (0)	34 (8.4)	4 (1)	.7
Hospital mortality	9 (18)	0 (0)	20 (4.9)	0 (0)	<.001

ICU = intensive care unit; IQR = interquartile range; KDIGO = kidney disease improving global outcomes; VAS = visual analogue scale.

(see Table S2, Supplementary Material): this collateral finding might be influenced by the fact that the vast majority of the population under study underwent elective surgery. In fact, these patients after being "nothing to eat or drink from midnight" may be relatively hypovolaemic and therefore more prone to developing atrial fibrillation.

Some specific evidence that epidural anaesthesia and analgesia improves several major outcomes in vascular surgery already exists.[9,17–19] Local anaesthetics might, indeed, exert an immediate beneficial effect on the cardiovascular system, as they block the sympathetic afferent and efferent nerve fibres, increase the diameter of stenotic epicardial coronary arteries, optimise the balance between the myocardial oxygen demand—supply ratio,[19] improve left ventricular function, and decrease anginal symptoms.

The literature shows contrasting results regarding the effect of thoracic epidural anaesthesia on mortality in major surgery and particularly in vascular surgery. The present study did not show any significant difference in mortality rate between the two groups, confirming previously reported results in major and vascular surgery settings.[7,20–22]

Recently, Bardia et al. have suggested that combined epidural with GA vs. GA alone was associated with significantly lower mortality and morbidity in patients undergoing elective abdominal aneurysm open repair.[6,23] However, TAAA surgery is more complex and presents unique features which may account for the different results observed.

Table 4. Multivariable logistic regression analysis of the whole patient population

	Thoracic epidural anaesthesia	
	OR (95% CI)	*p*-value
Hospital mortality	0.401 (0.077–2.08)	.3
Atrial fibrillation	0.47 (0.23–0.95)	.04
Acute kidney injury	0.39 (0.21–0.71)	.002
Need for renal replacement therapy	1.26 (0.39–3.99)	.7
Pulmonary complication	0.58 (0,18–1.84)	.4
Non-invasive mechanical ventilation	1.17 (0.67–2.04)	.6
Acute myocardial infarction	0.189 (0.05–0.64)	.008
Paraplegia	0.31 (0.157–0.615)	.001
Any complication	0.8 (0.25–2.59)	.7
Visual analogue scale	0.003 (0.0007–0.009)	< .001

OR = Odds ratio; CI = confidence interval.

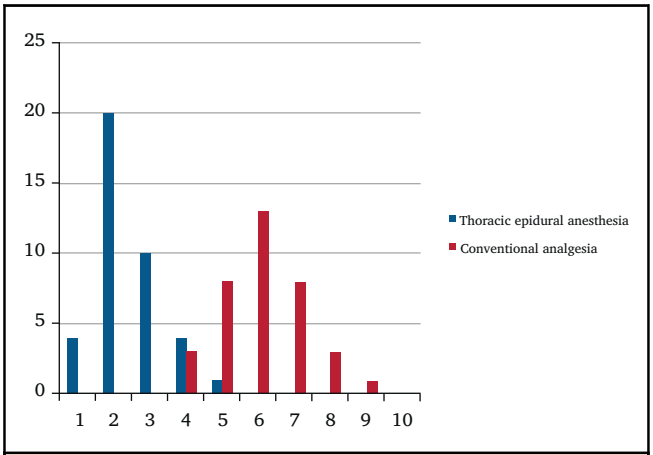

Figure 1. Visual analogue scale (VAS) in the propensity matched population. The graphic reports the number of patients (*y* axis) in each VAS value class (*x* axis).

Table 5. Univariable analysis of the 1:1 propensity matched study groups

Variable	Conventional analgesia (*n* = 43)	Thoracic epidural anaesthesia (*n* = 43)	*p*-value
Inotropes	12 (28)	16 (37)	.4
Visual analogue scale (VAS)	6 (5–7)	2 (2–3)	<.001
VAS scale ≥ 5	33 (92)	1 (3)	<.001
Acute kidney injury (KDIGO stage)			.9
0	18 (42)	21 (49)	.5
1	13 (30)	12 (28)	.8
2	8 (19)	7 (16)	.8
3	4 (9)	3 (7)	.9
Renal replacement therapy	1 (2)	2 (5)	.9
Pulmonary complications	10 (23)	7 (16)	.4
Atrial fibrillation	6 (14)	6 (14)	.9
Peri-operative acute myocardial infarction	0 (0)	1 (2)	.9
Bowel ischaemia	0 (0)	0 (0)	–
Paraplegia	3 (7)	4 (10)	.7
Hospital mortality	7 (16)	4 (9)	.5

Data are *n* (%) or median (interquartile range). KDIGO = kidney disease improving global outcomes.

Furthermore, the present data concerning the incidence of neurological complications are encouraging, as no case of epidural haematoma was recorded in a context in which patients require systemic intra-operative heparinisation and are at high risk of developing peri-operative coagulopathy secondary to massive bleeding and need for transfusions.[3]

Fitzgibbon et al. reported a case of paraplegia in a patient undergoing open thoracic aneurysm repair in which thoracic epidural anaesthesia was performed,[24] but the role of epidural anaesthesia itself was uncertain overall. A meta-analysis performed by Ruppen et al. demonstrated that the maximum risk of epidural haematoma was estimated to be 1700 for epidural anaesthesia in vascular surgery.[25]

Additional data from Ho et al. and Landoni et al. further support the role of thoracic epidural anaesthesia in TAAA surgery.[26,27]

However, this study was not powered to assess epidural haematoma incidence; therefore, no statements about safety of thoracic epidural anaesthesia in TAAA surgery can be made.

In recent years, transverse abdominal plane (TAP) block has been studied as alternative to epidural anaesthesia for post-operative analgesia in abdominal surgery.[28–31] Indeed, it represents a safe alternative with lower risks of complications, and haemodynamic effects vs. EA. Preliminary evidence suggests that TAP block seems to be non-inferior to EA for post-operative pain control,[32] even in patients undergoing open abdominal aortic aneurysm repair.[33,34] However, its use has never been documented in TAAA surgery albeit it may represent, associated with a multimodal pain management strategy, a valuable option in patients undergoing TAAA surgery in emergency conditions and when epidural anaesthesia is not feasible.

Overall, the present study is in line with current guidelines on this topic,[35] and investigating the peri-operative pain control and its eventual implications might fuel new, larger prospective and randomised trials on pain management.

This study has some limitations: first is the retrospective nature of its design. This partially explains the lack of some data, such as the rate of bloody tap during epidural catheter insertion or the rate of missing values of some variables. However, data included in the study were recorded consistently for all patients and represent a solid basis for analysis. The differing number of patients between groups and the differing characteristics between the two population at baseline were overcome by the matched analysis, in which 18 pre-operative and intra-operative variables were well balanced.[36] Second, on the one hand, the VAS scale is patient dependent and not strictly objective and reproducible, on the other hand it remains the most widely used pain score in clinical practice.[37] Furthermore, as the current

study was pragmatic, the VAS scale is particularly appropriate to assess the efficacy of post-operative analgesia. Third, if it is true that recording of the highest VAS value during the first post-operative day may have led to patients' "overall" pain being missed, the worst post-operative pain is usually perceived in the first 24 h. Thus, recording the highest VAS score during the first post-operative day can be considered a reliable measure of the worst post-operative pain suffered by patients. Fourth, if the large analysis appears redundant and excessive, it was needed to provide data that were as complete as possible on a relatively new topic in this setting. Finally, although epidural catheter and CSFD are done the day before the surgery in some centres, this is not standard practice at the authors' hospital. In addition, CSFD the day before may be harmful owing to the risk of catheter mis-positioning and can contribute to patient discomfort due to the manoeuvre itself (large bore needle, catheter tunnelling, stiches) and the need to remain in the supine position for at least 8 h after insertion.

In conclusion, thoracic epidural anaesthesia is effective in reducing post-operative pain in the context of open TAAA repair. Preliminary evidence also suggests that thoracic epidural anaesthesia might also have systemic effects that may play a role in reducing post-operative complications. The effect of thoracic epidural anaesthesia on post-operative major outcomes in patients with TAAA is still not fully documented and further prospective randomised studies are warranted in this context.

CONFLICTS OF INTEREST

None.

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APPENDIX A. SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejvs.2018.09.027.

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