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RESEARCH ARTICLE

Comparison of Four Different Block Techniques for Postoperative Analgesia in Thoracotomy

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ABSTRACT

Objectives: Postthoracotomy pain requires multimodal perioperative management, including systemic and regional techniques. This prospective, randomized study aimed to evaluate postthoracotomy pain scores using the visual analog scale (VAS) as well as consumption of analgesic in 24 h and complications.

Methods: The patients were randomly assigned into four groups (25 patients each group) according to the analgesia technique used: Intercostal nerve block (ICB), thoracic epidural block (TEB), ultrasonography-guided erector spinae plane block (ESPB), and ultrasonography-guided thoracic paravertebral block (TPVB) groups. Multimodal analgesia was achieved with tramadol, paracetamol, and intravenous pethidine via patient-controlled analgesia (PCA) for all patients. The VAS scores at 30, 60, 90, 120 min, 6, 12, and 24 h postoperatively, consumption of analgesic at the first 24 h, rescue analgesic requirement, and side effects were recorded.

Results: The VAS scores were the highest in the ICB group and the lowest in the TPVB group at all time periods after thoracotomy ($p<0.05$). Likewise, total pethidine dose, number of PCA trials, and PCA data were determined to be at least in the TPVB group. However, only the number of PCA trials was found to be statistically significant ($p=0.03$). In terms of side effects, no difference was observed between the groups. Nausea and vomiting occurred in two patients in the ICB and ESPB groups, whereas hypotension occurred in two patients in the TEB group.

Conclusion: In conclusion, ultrasound-guided single-injection TPVB is more reliable and preferable in thoracotomy, as it is associated with low pain scores and has no side effects.

Keywords: Erector spinae plane block, intercostal nerve block, postoperative analgesia, thoracic epidural blocks, thoracic paravertebral blocks, thoracotomy

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Introduction

Postoperative pain is a process that begins with surgical trauma and ends with tissue healing.[1] Thoracotomy is one of the most painful surgical procedures, and it has a complex and multifactorial pathogenesis. Pain following thoracotomy substantially reduces patient satisfaction and quality of life as well as increases the risk of postoperative complications (respiratory complications including hypoventilation, hypoxemia, atelectasis, pulmonary infections, and respiratory failure), thromboembolism, and even mortality.[2] Thoracotomy pain is also known to be associated with the intercostal, sympathetic, vagus, and phrenic nerves.[3] The multifactorial nature of thoracotomy pain prevents the use of any single analgesic technique to block all reported pain afferents. Success is more possible with a multimodal approach that targets multiple sites along the pain pathway and combines regional anesthesia with nonsteroidal anti-inflammatory drugs, opioids, or other parenteral drugs. Over the years, various drug combinations and techniques have been developed and used to control pain following thoracotomy.

While systemic opioids were the mainstay of postthoracotomy analgesia until the early 1980s, thoracic epidural block

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(TEB) became the gold standard for postthoracotomy analgesia in the 1990s.[4] However, although rare, there are risks of complications such as spinal cord injury, infection, hematoma, postdural puncture headache, and catheter migration.[2] Recently, thoracic paravertebral block (TPVB) has been considered to be an alternative method for inducing analgesia following thoracotomy.[5] TPVB is also associated with complications such as nerve injury, vascular and dural punctures, hypotension, and pneumothorax.[1,5] Erector spinae plane block (ESPB) is a relatively new regional peripheral nerve block that has gained popularity for thoracic surgery.[6] Various complications of ESB have been reported, such as pneumothorax, intestinal injury, nerve damage, local anesthetic systemic toxicity, and block failure.[5] Intercostal nerve block (ICB) is a simple, fast, easy, and direct method of injecting local anesthetic by the surgeon or anesthesiologist into the five intercostal nerves corresponding to the dermatomes affected by the incision to provide analgesia.[7] Complications of ICB such as pneumothorax, bleeding, local anesthetic systemic toxicity, nerve injury, and block failure have also been reported.[5] However, it remains unknown which technique is the safest, most effective, and most applicable to all patients. Therefore, this study aimed to compare the efficacy and side effects of the methods used to provide analgesia following thoracotomy. The primary outcome was postoperative pain visual analog scale (VAS) scores at 30, 60, 90, 120 min, 6, 12, and 24 h postoperatively. The secondary outcomes were amount of consumption analgesic in 24 h and side effects such as hypotension, bradycardia, nausea, vomiting, urinary retention, and neurological disorders.

Methods

After obtaining ethics committee approval (decision no.: 514/192/20, Date: 30/12/2020), 100 patients with ASA risk scores I–III aged 18 years above who underwent elective thoracotomy between February 2021 and February 2022 were included in our prospective, randomized, controlled study. Written informed consent was obtained from all the patients for the interventions and registration into the study. The study was conducted in accordance with the principles of the Declaration of Helsinki of 1964. The exclusion criteria were refusal of the patient or family to provide written consent; patients kept on ventilator postoperatively; age <18 years; coagulation; severe hepatic, renal, cardiac, neuromuscular, and endocrinological disorders; known allergy to local anesthetic drugs, body mass index (BMI) >40 kg/m^2, infection at the injection site, pregnancy, emergency operations, preoperative chronic pain, and use of continuous analgesics. At the preoperative visit, all patients were instructed on how to assess their own pain using a 10-cm VAS (0=no pain, 10=worst possible pain) and how to use the patient-controlled analgesia (PCA) device. All the patients were subjected to standard monitoring and anesthesia management. Lung separation was achieved using a double-lumen tube in all patients. The surgical procedures were performed by the same team of surgeons. Before closing the incision, 1 mg/kg of tramadol and 1 g of paracetamol were intravenously administered to the patients. At the end of surgery, the patients were consecutively randomized into one of the following groups: ICB, TPVB, ESPB, and TEB groups. In the operating room, the patients were informed and randomized into groups using the envelope draw method. All blocks were performed by the same experienced anesthetist under ultrasound guidance.

ICB: After closing the incision, ICB (0.5% bupivacaine [Bustesin 0.5%, Vem Pharmaceutical, Türkiye] 20 mL) was applied to the skin in three segments, namely, the upper and lower segments of the incision line, by the same surgeon for its direct visibility. The block application was carried out by entering the lower end of the ribs with an injector needle immediately below the line where the neurovascular bundle was thought to pass.

ESPB: At the end of surgery, ultrasound-guided ESPB was applied at the level where the surgical incision was made (T4–T7) by an anesthesiologist while the patients were in the lateral decubitus position. A linear ultrasound probe (Esaote My Lab 6, Florence, Italy) was placed parasagittally in the midline from the appropriate dermatome area, and the spinous processes were visualized. Subsequently, the probe was moved laterally, and the transverse processes, erector spinae, and rhomboid and trapezius muscles were visualized. Using the "in-plane" technique, the needle was advanced in the craniocaudal direction, and 20 mL of bupivacaine (Bustesin 0.5%,Vem Pharmaceutical, Türkiye) at a 0.5% concentration was injected between the erector spinae muscle and the transverse process (Fig. 1a).

TPVB: At the end of surgery, ultrasound-guided paravertebral blockade was performed at the level where the surgical incision was made (T4–T7) by an anesthesiologist while the patients were in the lateral decubitus position. A linear 10–18-MHz ultrasound probe (Esaote MyLab Six, Florence, Italy) was placed between the two transverse processes in the paramedian plane at the level of the thoracotomy. Under ultrasound guidance, an 18-gauge 10-mm needle (Pajunk, Geisingen, Germany) was advanced using the in-plane technique until it passed the superior costotransverse ligament. With the needle tip in the TPVB area, 20 mL of 0.5% bupivacaine (Bustesin 0.5%, Vem Pharmaceutical, Türkiye) was injected after it was aspirated to control the presence of blood and/or air. Depression of the pleura was observed with the spread of the local anesthetic (Fig. 1b).

TEB: At the end of surgery, the patients were placed in the lateral decubitus position, and the epidural space (T5–6) was entered from the midline using a 16-gauge Tuohy needle (Epidural Minipack, Portex, Türkiye) using the loss-of-

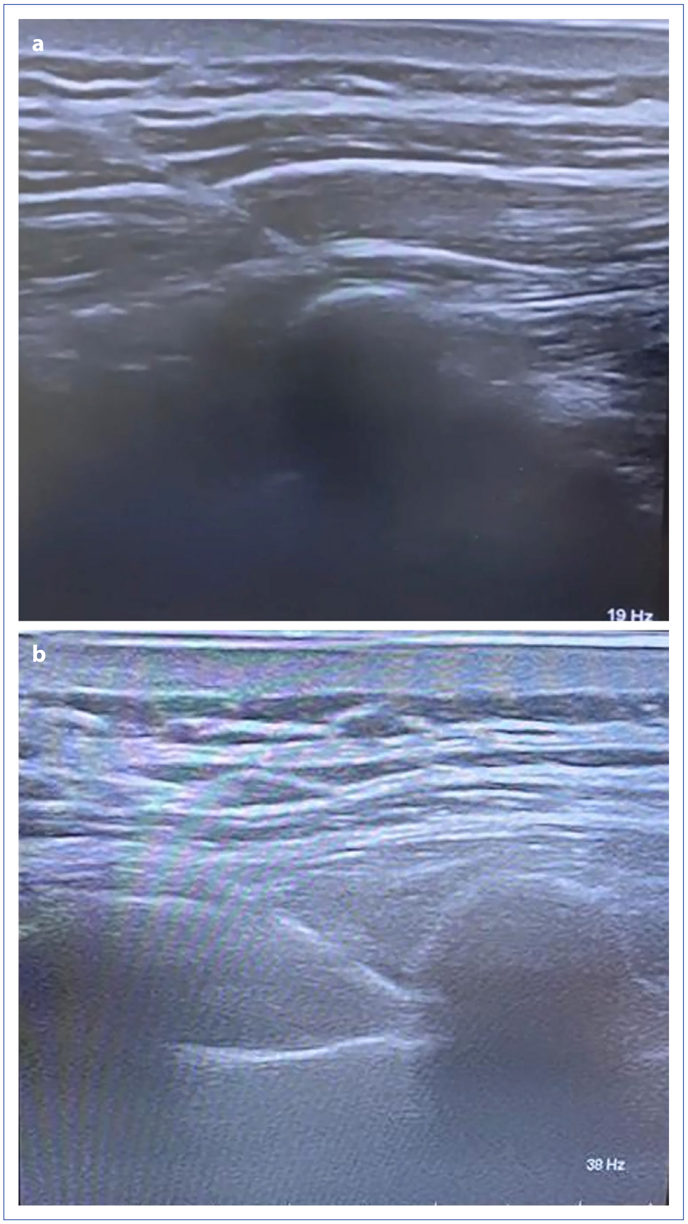

Figure 1. (a) Sonographic image of the erector spinae plane block. **(b)** Sonographic image of the thoracic paravertebral block.

resistance technique by an anesthesiologist. For TEB, 10 mL of 0.5% bupivacaine (Bustesin 0.5%, Vem Pharmaceutical, Türkie) was administered into the epidural space.

All the doses used in the blocks were determined after our literature review.[8] The patients were extubated, and a PCA device was intravenously (iv) installed in the postoperative recovery room. Intraoperatively, blood pressure and heart rate were recorded every 15 min. Pethidine HCl was administred as an iv bolus mg, lockout time 20 min, maximum dose of 3 mg/kg for 4 hours, and no continuous infusion. Tramadol (1 mg/kg) was administered as a rescue analgesic to patients with VAS >4 postoperatively. Age, sex, height, weight, BMI, operation type, operation time, postoperative VAS scores (30, 60, 90, 120 min, 6, 12, and 24 h), postoperative PCA cumulative analgesic dose and side effects (nausea, vomiting, hypotension, bradycardia, etc.), and PCA data (number of analgesics given by the device) were recorded. The parameters were checked by the same anesthesia assistant who was unaware of the patient allocation in the recovery room and thoracic surgery service.

Statistical Analysis

Data were entered into the Statistical Package for the Social Sciences (IBM®SPSS Statistics for Windows, version 23.0, Armonk, NY, USA) software. Descriptive statistics were used. Quantitative variables were expressed as mean, maximum (max), and minimum (min) values and qualitative variables as percentages. Whether the distributions were normal or not was determined via Kolmogorov–Smirnov analysis. Normal distributions were expressed as mean values, and Student's t-test was employed for intergroup comparisons. Pearson's chi-squared test was employed for the comparative analysis of qualitative variables; however, Fisher's exact test was used if the sample size was small (≤5). Nonparametric continuous variables were expressed as medians and interquartile range. Because there were more than two groups, comparisons were made via one-way analysis of variance; if the distribution was normal, *post hoc* evaluation was conducted using Tukey's test; otherwise, Games–Howell was employed. In-group and between-group comparisons were made. P<0.05 was considered to indicate statistical significance.

Results

The majority of the patients were men (n=70, 70%), and the median age was 61 (13) years (min=20, max=82, median=61 years). The most common type of operation was lobectomy (n=48, 48%). For all patients, the mean duration of surgery was 174.1±5.3 min (min=80, max=440, median=160 min) and the mean duration of anesthesia was 195.6±5.8 min (min=90, max=480, median=180 min).

The demographic and clinical comparisons of the block groups are shown in Table 1. No statistical difference was observed between the groups in terms of age, sex, BMI, American Society of Anesthesiologist (ASA) score, and duration of anesthesia and surgery. However, statistically significant differences were observed in terms of the type of operation (p=0.007).

The VAS scores exhibited statistically significant difference between the block groups according to the in terms of evaluation times (Table 2).

The ICB group had the highest VAS scores at all evaluation times. The VAS scores did not statistically significantly differ between the ICB and ESPB groups, except at 60 min. However, a statistically significant difference in the VAS scores was observed between these groups at 90, 120 min, and 6 h. When

Table 1. Comparison of the block groups in terms of demographic and clinical data

Variables	ICB		ESPB		TPVB		TEB		p
	n	%	n	%	n	%	n	%	
Age, years, median (IQR)	60	12.5	60	15.5	62	12.0	65	13.5	0.383
Sex									0.614
Male	18	72	18	72	17	68	17	68	
Female	7	28	7	28	8	32	8	32	
BMI, kg/m^2, median (IQR)	26.1 (5.0)		25.3 (4.4)		25.0 (3.0)		26.2 (4.1)		0.232
ASA									0.936
1					–		–		
2	2	8	2	8	1	4	1	4	
3	23	92	23	92	24	96	24	96	
Anesthesia duration, minutes, median (IQR)	180 (80)		180 (60)		180 (42)		190 (75)		0.747
Surgery duration, minutes, median (IQR)	160 (82.5)		160 (55)		160 (35)		170 (65)		0.718
Type of operation									0.007[α]
Lobectomy	12	48	10	40	13	52	20	80	
Pneumonectomy	2	8	2	8	4	16	3	12	
Wedge resection	8	32	10	40	6	24	2	8	
Other	3	12	3	12	2	8	–		

[α]: Statistically significant difference between the ICB and TEB groups (p=0.02) as well as ESPB and TEB groups (p=0.003). ICB: Intercostal nerve block; ESPB: Erector spinae plane block; TPVB: Thoracic paravertebral block; TEB: Thoracic epidural block; n: Number; IQR: Interquartile range; BMI: body mass index; ASA: American Society of Anesthesiology.

Table 2. Temporal status of static visual analog scale scores and comparison between the groups÷

Variables	ICB	ESPB	TPVB	TEB	p	p^1	p^2	p^3	p^4	p^5	p^6
VAS 30, mean±SD	4.3±0.5	4.0±0.7	3.7±0.7	3.8±0.4	**0.003**	0.417	**0.007**	**0.005**	0.301	0.496	0.902
VAS 60, mean±SD	4.3±0.5	3.8±0.6	3.5±0.6	3.8±0.8	**<0.001**	**0.02**	**<0.001**	**0.01**	0.282	0.995	0.367
VAS 90, mean±SD	4.1±0.4	3.7±0.5	3.4±0.5	3.8±0.5	**0.001**	0.08	**<0.001**	0.211	0.349	0.961	0.129
VAS 120, mean±SD	4.0±0.4	3.6±0.6	3.3±0.4	3.7±0.5	**<0.001**	0.06	**<0.001**	0.257	0.315	0.902	0.06
VAS 6, mean±SD	4.0±0.5	3.6±0.6	3.3±0.4	3.7±0.4	**<0.001**	0.06	**<0.001**	**0.02**	0.116	1.000	**0.04**
VAS 12, mean±SD	4.0±0.5	3.6±0.6	3.3±0.4	3.7±0.5	**0.001**	0.170	**<0.001**	0.301	0.200	0.964	**0.03**
VAS 24, mean±SD	3.9±0.6	3.6±0.6	3.2±0.4	3.6±0.6	**<0.001**	0.193	**<0.001**	0.235	0.112	0.996	**0.03**

Bold p-values indicate statistical significance. Italic p-values indicate p-values close to statistical significance. p^1: ICB vs ESPB; p^2: ICB vs TPVB; p^3: ICB vs TEB; p^4: ESPB vs TPVB; p^5: ESPB vs TEB, p6: TPVB vs TEB. VAS: visual analog scale; SD: standard deviation.

the ICB and TPVB groups were compared, the VAS scores were higher in the former group than in the latter at all evaluation times. When the ICB and TEB groups were compared, the VAS scores measured at 30 min, 60 min, and 6 h were found to be statistically lower in the latter. The VAS scores did not statistically significantly differ between the ESPB and TPVB groups or between the ESPB and TEB groups at any evaluation time. When the TPVB and TEB groups were compared, the VAS scores were found to be statistically higher in the latter group than in the former at 6 min, 12 min, and 24 h.

The changes in the VAS scores according to the block groups for each evaluation time are shown in Figure 1.

Table 3 shows the comparison of the block groups in terms of the total pethidine dose, number of PCA trials, and PCA data. While no statistical difference was observed between the groups in terms of total pethidine dose and PCA data, there was a difference between the groups in terms of the number of PCA trials. The number of PCA trials was found to be statistically lower only in the TPVB group than in the ICB group (p=0.02), but there was no statistical difference between the other groups.

Side effects developed in four (4%) patients. Nausea and vomiting occurred in two patients (ICB and ESPB groups) and hypotension in two patients (TEB group). No statistical difference was observed between the groups in terms of complications (p=0.650).

During follow-up, three of the patients required rescue analgesics (3%), of whom two were from the ICB group and one from the ESPB group.

Discussion

Although intravenous PCA can generally be applied to all patients for postoperative analgesia, multimodal analgesic

Table 3. Comparison of the block groups in terms of total pethidine dose, patient-controlled analgesia trial, and patient-controlled analgesia data

Variables	ICB	ESPB	TPVB	TEB	p	p²
Total pethidine dose, mean±SD (mg)	256.8±96.3	228.0±96.0	199.2±93.1	202.4±93.3	0.120	0.153
PCA trial, mean±SD	23.0±14.7	17.6±14.7	13.2± 7.0	16.0±10.3	**0.03**	**0.02**
PCA data, mean±SD	12.8±4.6	11.5±4.8	10.0± 4.6	10.4±5.2	0.201	0.174

p²: ICB vs TPVB; bold P-values indicate statistical significance. PCA: patient-controlled analgesia.

strategies combining different techniques and drugs have been recommended in recent years due to its side effects such as nausea, vomiting, respiratory depression, and sometimes insufficient analgesia. However, because the literature on multimodal analgesic therapy remains insufficient, we aimed to explore the effect of ICB, ESPB, TPVB, and TEB applied after thoracotomy on postoperative analgesia in this randomized, controlled study. At the end of the prospective study, we determined that all blocks provided adequate pain control in the first 24 h after thoracotomy. However, it was determined that the VAS score were highest in the ICB group and lowest in the TPVB group at all time periods. To the best of our knowledge, no other prospective study comparing the analgesic efficacy and reliability of these four techniques in thoracotomy has been conducted. Therefore, we think that this study may be interesting.

TEB has been a standard technique for pain control following thoracotomy for several years.[4] However, it has disadvantages such as technical difficulty in administration, high failure rate even when performed by experts, hemodynamic effects in the form of hypotension and bradycardia, epidural hematoma, dural puncture, neuropathy, and patchy block.[9] For this reason, peripheral blocks have been used more frequently than central blocks. According to the Enhanced Recovery After Surgery (ERAS) protocols in thoracic surgery, regional anesthesia is recommended to reduce postoperative opioid use.[10] In recent years, techniques such as ICB, ESPB, and TPVB, which have the advantages of providing unilateral analgesia with lower side-effect profiles, have gained popularity as alternatives to TEA.

In the study by Turhan et al.[8] that compared three techniques, TBVP, ESPB, and ICB, for providing postoperative analgesia to patients who were planned to undergo video-assisted thoracoscopic surgery (VATS), all three blocks provided sufficient analgesia, but when compared with ESPB and ICB, TPVB was a preferable method with more successful analgesia and less morphine consumption; this finding is consistent with the findings of our study.

In the study by Sun et al.[11] that applied ICNB, ESPB+ICNB, or TPVB+ICNB for postoperative analgesia in patients planned to undergo VATS operation, they reported that the analgesic effect of TPVB+ICNB was superior to that of ICNB and that the analgesic effect of ESPB was similar to those of TPVB and ICB. In our study using a single technique, unlike the researchers,[11] we determined that the analgesic efficiency of TPVB was higher than that of ICNB and that there was no difference between the groups in terms of narcotic consumption and additional analgesic requirement, which is consistent with the results of the researchers.[11]

When TPVB was compared with TEA, the evidence for pain control was controversial. Similar to our results, although there are some studies reporting the advantages of TVPB over TEA,[12,13] some also demonstrated that the two techniques exhibit equal clinical efficacy.[14,15] However, these studies also reported that TBVB is more advantageous than TEB, at least in terms of side effects.[13– 15] In their meta-analysis of 520 patients who underwent thoracotomy and 10 randomized studies, Davies et al.[16] reported that TPVB provides analgesia comparable to TEB following surgery, , even has a little side-effect profile, and can be recommended for major thoracic and upper abdominal surgeries, which is consistent with our results. Injection of local anesthetic into the wedge-shaped space as the spinal nerves exit the intervertebral foramen induces effective somatosensory and sympathetic nerve blockade to manage unilateral pain from the chest and abdomen. TPVB can be applied in a single- or double-sided manner. Unlike TEB, TPVB can be used to avoid contralateral sympathectomy, thus minimizing hypotension and leading to better maintenance of blood pressure. Although we did not observe any difference in terms of complications between the groups in our study, two patients experienced nausea and vomiting (from the ICB and ESPB groups), and two patients developed hypotension (both from the TEB group). In our study, no side effects occurred in the TPVB group. Therefore, we believe that TPVB is a promising alternative for postoperative analgesia in thoracic surgery.

In our more recent literature review of thoracic epidural analgesia, which is considered to be the "gold standard" in thoracotomy, it has been observed that TPVB provides postoperative analgesia comparable to TEA, mostly in line with the results of our study.[17,18] It is reported as high evidence that TPVB provides analgesia equivalent to TEB according to the ERAS protocols in thoracic surgery.[10]

Limitations

Our study had several limitations. First, it was a single-center study with a limited sample size, enrolling only 100 patients. Secondly, the analgesic effect was evaluated using a subjective indicator, as there was no objective indicator measuring the pain index. Third, some of the patients continued to experience pain for a long time after the operation. Therefore, the patients needed to be followed up for a longer period of time. However, this could help us better evaluate and compare the analgesic effects.

Conclusion

Thoracotomy is one of the most painful surgical procedures. Effective postoperative pain management is an important part of the ERAS protocol in thoracic surgery. In patients undergoing thoracic surgery, analgesic treatment should be carefully planned and executed using a multimodal approach that includes regional and systemic analgesia. Although ICB, ESPB, TPVB, and TEB are effective analgesic techniques for the relief of acute pain following thoracotomy, it has been concluded that ultrasound-guided single-injection TPVB is safer as it provides more successful analgesia and has no side effects compared with TEB, which has been the gold standard in thoracotomy until recently, as well as other techniques.

Disclosures

Ethics Committee Approval: The study was approved by The Kartal Dr. Lütfi Kırdar City Hospital Clinical Research Ethics Committee (no: 514/192/20, date: 30/12/2020).

Authorship Contributions: Concept – F.D.G., G.A., J.S.K., K.T.S., M.T.D.; Design – F.D.G., U.D.H., K.T.S.; Supervision – F.D.G., G.A., J.S.K., K.T.S., U.D.H., R.D., M.T.D.; Materials – F.D.G., M.T.D.; Data collection &/or processing – F.D.G., G.A., U.D.H., K.T.S., M.T.D.; Analysis and/or interpretation – F.D.G., G.A., J.S.K., K.T.S., U.D.H., M.T.D.; Literature search – F.D.G., G.A., J.S.K., U.D.H., M.T.D.; Writing – G.A., J.S.K., F.D.G.; Critical review – F.D.G., G.A., K.T.S., R.D.

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