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REVIEW ARTICLE/BRIEF REVIEW

Transversus abdominal plane block for postoperative analgesia: a systematic review and meta-analysis of randomized-controlled trials

Le bloc dans le plan du muscle transverse de l'abdomen pour réaliser une analgésie postopératoire: revue systématique et méta-analyse des études randomisées contrôlées

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Abstract

Purpose *The transversus abdominal plane (TAP) block has been described as an effective pain control technique after abdominal surgery. We performed a systematic review and meta-analysis of randomized-controlled trials (RCTs) to account for the increasing number of TAP block studies appearing in the literature. The primary outcome we examined was the effect of TAP block on the postoperative pain score at six, 12, and 24 hr. The secondary outcome was 24-hr morphine consumption.*

Source *We searched the United States National Library of Medicine database, the Excerpta Medica database, and the Cochrane Central Register of Controlled Clinical Studies and identified RCTs focusing on the analgesic efficacy of TAP block compared with a control group [i.e., placebo, epidural analgesia, intrathecal morphine (ITM), and ilioinguinal nerve block after abdominal surgery]. Meta-analyses were performed on postoperative pain scores at rest at six, 12, and 24 hr (visual analogue scale, 0-10) and on 24-hr opioid consumption.*

Principal findings *In the 51 trials identified, compared with placebo, TAP block reduced the VAS for pain at six hours by 1.4 (95% confidence interval [CI], −1.9 to −0.8; P < 0.001), at 12 hr by 2.0 (95% CI, −2.7 to −1.4; P < 0.001), and at 24 hr by 1.2 (95% CI, −1.6 to −0.8; P < 0.001). Similarly, compared with placebo, TAP block reduced morphine consumption at 24 hr after surgery (mean difference, −14.7 mg; 95% CI, −18.4 to −11.0; P < 0.001). We observed this reduction in pain scores and morphine consumption in the TAP block group after gynecological surgery, appendectomy, inguinal surgery, bariatric surgery, and urological surgery. Nevertheless, separate analysis of the studies comparing ITM with TAP block revealed that ITM seemed to have a greater analgesic efficacy.*

Conclusions *The TAP block can play an important role in the management of pain after abdominal surgery by reducing both pain scores and 24-hr morphine consumption. It may have particular utility when neuraxial techniques or opioids are contraindicated.*

Résumé

Objectif *Le bloc dans le plan du muscle transverse de l'abdomen (ou TAP bloc) a été décrit comme une technique efficace de contrôle de la douleur après une chirurgie abdominale. Nous avons réalisé une revue systématique et une méta-analyse des études randomisées contrôlées (ERC) pour faire un état des lieux du nombre croissant d'études*

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sur le TAP bloc qui s'ajoutent à la littérature. Le critère d'évaluation principal était l'effet d'un TAP bloc sur les scores de douleur postopératoire à six, 12 et 24 h. Le critère d'évaluation secondaire était la consommation de morphine à 24 h.

Source *Nous avons effectué des recherches dans la base de données de la Bibliothèque nationale américaine de médecine (United States National Library of Medicine) ainsi que dans le Registre central Cochrane des études cliniques contrôlées (Cochrane Central Register of Controlled Clinical Studies). Nous avons ensuite identifié les ERC se concentrant sur l'efficacité analgésique des TAP blocs par rapport à un groupe témoin [c.-à-d. placebo, analgésie péridurale, morphine intrathécale (MIT) et bloc nerveux ilio-inguinal] après une chirurgie abdominale. Des méta-analyses ont été réalisées en examinant les scores de douleur postopératoire au repos à six, 12 et 24 h (échelle visuelle analogique [EVA], 0-10) et la consommation d'opioïdes sur une période de 24 h.*

Constatations principales *Parmi les 51 études identifiées, par rapport à un placebo, le TAP bloc a réduit le score de douleur de 1,4 sur l'EVA après six heures (intervalle de confiance [IC] 95 %, −1,9 à −0,8; $P < 0,001$), de 2,0 après 12 h (IC 95 %, −2,7 à −1,4; $P < 0,001$) et de 1,2 après 24 h (IC 95 %, −1,6 à −0,8; $P < 0,001$). De la même façon, par rapport au placebo, le TAP bloc a réduit la consommation de morphine à 24 h après la chirurgie (différence moyenne, −14,7 mg; IC 95 %, −18,4 à −11,0; $P < 0,001$). Nous avons observé cette réduction en matière de scores de douleur et de consommation de morphine dans le groupe TAP bloc après des chirurgies gynécologiques, des appendicectomies, des chirurgies inguinales, des chirurgies bariatriques et des chirurgies urologiques. Toutefois, une analyse séparée des études comparant la MIT au TAP bloc a révélé que la MIT semblait avoir une efficacité analgésique plus prononcée.*

Conclusion *Le TAP bloc peut jouer un rôle important dans la prise en charge de la douleur après une chirurgie abdominale en réduisant les scores de douleur et la consommation de morphine à 24 h. Il pourrait être particulièrement utile lorsque l'utilisation de techniques neuraxiales ou les opioïdes sont contre-indiqués.*

The first description of the transversus abdominal plane (TAP) block consisted of a loss-of-resistance technique with the local anesthetic administered into the triangle of Petit (i.e., the area confined within the iliac crest, the latissimus dorsi, and the external abdominal oblique muscle).[1] Since then, numerous variations of this approach have been suggested to overcome the significant variability of local anesthetic spread demonstrated in cadaveric studies.[2-4]

In recent years, TAP block has gained popularity as an effective pain relief technique in patients undergoing a variety of abdominal operations. An increasing number of randomized-controlled trials (RCTs) and case reports in the literature have highlighted the analgesic effectiveness of the TAP block and proposed it as an alternative pain management technique in patients with contraindications to the use of opioids and/or neuraxial anesthesia. Indeed, TAP block avoids the risk of neuraxial complications in all patients.

Previous reviews and meta-analyses have all had some limitations. For example, these prior reports have included a relatively small number of studies that were often limited to very specific surgical settings. For example, a 2010 Cochrane Review of the analgesic effectiveness of TAP block after abdominal surgery included only five trials.[5] In 2012, Abdallah *et al*. subsequently reported a systematic review and meta-analysis of TAP block for pain relief after Cesarean delivery that included results from five trials,[6] and in 2013, Champaneria *et al*.[7] performed a similar meta-analysis of five trials of TAP block after hysterectomy. A more recent and larger meta-analysis from 2013[8] included ten RCTs of TAP block but was restricted to only laparoscopic surgery. Since then, numerous TAP block RCTs have been published warranting an updated review.

In this systematic review and meta-analysis, we address the analgesic efficacy of TAP blocks after abdominal surgery. The primary outcome is the difference in postoperative pain scores at rest at six, 12, and 24 hr in patients following abdominal surgery with either a TAP block or an alternative analgesic technique (i.e., placebo, epidural analgesia, intrathecal morphine (ITM), ilioinguinal or iliohypogastric nerve block (IIN), and wound infiltration). The secondary endpoint examined was 24-hr morphine consumption.

Methods

The authors followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statements in preparing this review.[9]

The studies were retrieved from the United States National Library of Medicine database (MEDLINE®), the Excerpta Medica database (EMBASE™), and Cochrane Central Register of Controlled Clinical Studies (CENTRAL). The search criteria were ([transversus abdominis plane block]) AND ([analgesic efficacy] OR [analgesic effectiveness] OR [postoperative pain relief]) AND ([surgery] OR [abdominal surgery] OR [laparoscopic surgery]), without any restrictions for language. Databases were explored from January 1, 2004 to August 31, 2014. In addition, we conducted a hand search through the reference lists to identify any studies missed by the electronic search.

Our search was limited to published RCTs on human subjects comparing TAP block with placebo (i.e., saline or no block), epidural analgesia, ITM local infiltration, and other nerve blocks. Reviews, abstracts, letters to editors, meta-analyses, case reports, and retrospective studies were excluded. The authors screened the search results and removed duplicates. Complete paper copies were obtained for all studies not eliminated for irrelevance to the subject.

Exclusion criteria were studies of irrelevance to TAP block, technical descriptions/proceedings, studies in volunteers, dose-ranging studies of anesthetics, cadaveric evaluation of anesthetic spread, and studies that compared TAP block with anesthetic techniques not mentioned above. Studies were also excluded if they did not report postoperative pain scores at six, 12, or 24 hr, total analgesic consumption at 24 hr, or if the authors did not specify the time at which the data were recorded.

The selected articles were evaluated using the three-item five-point Jadad quality scale.[10] The score ranges from 0-5, and studies with low-quality scores (0-2) were not included.

A data collection sheet was created and data were extracted on anesthesia technique, type of surgery, American Society of Anesthesiologists physical status classification, TAP block technique (ultrasound-guided or landmark), timing of the block, site of injection, postoperative analgesia regimen, pain intensity scores at rest, opioid consumption, and side effects (nausea, vomiting, and sedation). One investigator (E.B.) was in charge of collecting the data and assessing the methodological validity of all the eligible studies. All data were then verified by two further investigators (S.C., T.M.).

The data were extracted from the articles retrieved using the *Cochrane Handbook for Systematic Reviews of Interventions*[1] and recommendations by Hozo *et al.*[11] Our primary outcome was a comparison of postoperative pain scores at rest between TAP block and control analgesic technique, measured by a visual or numerical scale (0-10 scale, where 0 = no pain and 10 = worst pain imaginable) at six, 12, and 24 hr. Any visual analogue scale (VAS) scores reported on a 0-100 scale were converted to a 0-10 scale for analysis. The secondary outcome was 24-hr opioid consumption. Any opiate drugs other than intravenous morphine where converted to morphine equivalents.[12,13] The endpoints were then examined by performing individual statistical analyses based on the type of surgery (i.e., Cesarean delivery, gynecological surgery, abdominal surgery).

If trials included more than two groups for comparison, in the final analysis, we included only the group that received a TAP block and the group that received the interventional procedure (i.e., epidural, ITM, wound infiltration, other nerve blocks). Trials were not included in the meta-analysis if data were not reported at the time selected as our primary outcome or if opioids were not used as analgesic drugs. We included only those studies that collected and reported total 24-hr opioid consumption (in mg) and that specified the time of data collection.

Publication bias was evaluated by analyzing the funnel plots.[14] Continuous data were summarized as mean (standard deviation, [SD]). The mean difference and the standardized mean differences with a 95% confidence interval (CI) were calculated. We used random effects modelling to analyse the data. Heterogeneity of the retrieved trials was evaluated using the I^2 statistic (where $I^2 > 75\%$ reflects a high heterogeneity). We performed subgroup analyses according to the TAP block technique (i.e., ultrasound, landmark technique, from inside the abdominal wall) as sensitivity analysis for the primary and secondary endpoints. Meta-analyses and subanalyses were performed when at least two trials reported our selected endpoints. All statistical analyses were performed using Review Manager (RevMan) Computer program Version 5.3 (Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2012). We also evaluated the quality of evidence for the outcomes reported in our systematic review and meta-analysis using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) system.[15]

Results

A flowchart of the literature search is shown in Fig. 1. Electronic literature searches identified 406 articles, which fulfilled the criteria of the review outlined above. Twelve further citations were found by hand searching. Duplicate studies were removed and the remaining articles were screened by abstract and titles for eligibility. From these citations, 72 full-text articles were obtained, and 21 studies were excluded after a more detailed inspection. Reasons for exclusion were irrelevance to the topic, retrospective studies, studies not randomized, cadaveric models, volunteer models, Jadad score 0-2, opioid consumption not collected, and studies that included only technical descriptions.

Our search retrieved 51 RCTs that satisfied our inclusion criteria. Characteristics of these articles are reported in Table 1. In the majority (36 of the 51) of the studies, TAP blocks were performed using ultrasound (US) guidance. In three studies, the injection of local anesthetic into the TAP was performed from inside the abdominal wall.[16-18] The remaining 12 studies used a non-US-guided loss-of-resistance technique. Tables 2 and 3 provide a summary of the statistical analysis (i.e., mean VAS differences, CI, *P* value, heterogeneity scores, and quality of the evidence [GRADE]) for each of the subcategories of TAP block use described below.

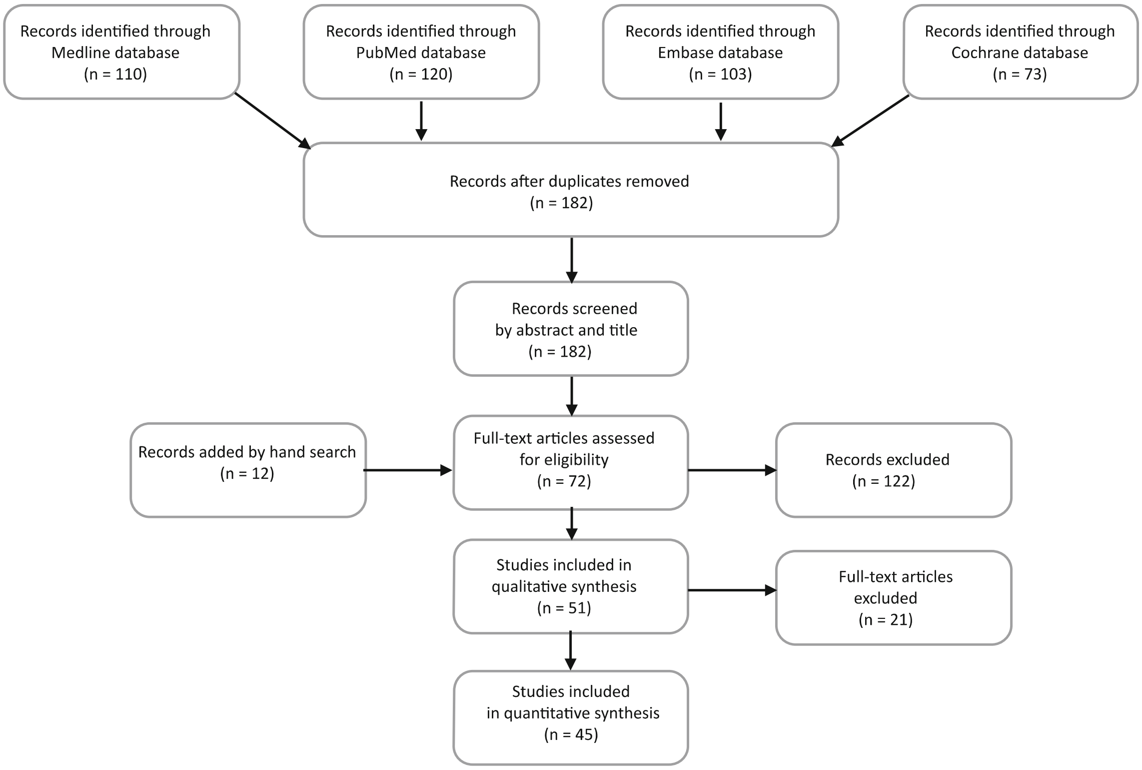

Fig. 1 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart summarizing retrieved, included, and excluded trials

Transversus abdominal plane block vs placebo

We identified 36 RCTs comparing TAP blocks with placebo (Table 2). Pain scores at six and 12 hr were investigated in 23[17-39] and 18[16-23,25,26,29,31,32,34-36,38-41] studies, respectively. The overall analyses showed that, in the TAP block group, the six-hour VAS pain score was reduced by 1.4 (95% CI, −1.9 to −0.8; $P < 0.001$) (Fig. 2), and the 12-hr pain score was reduced by 2 (95% CI, −2.7 to −1.4; $P < 0.001$) (Fig. 3). Heterogeneity was high (I^2=0.94, for both outcomes; Table 2). Thirty-three studies investigated the pain score at 24 hr and found a reduction of 1.2 (95% CI, −1.6 to −0.8; $P < 0.001$) in the TAP block group ($I^2 = 0.93$). Consumption of opioids at 24 hr after surgery was investigated in 28 studies, with a significant reduction in opioid intake of 14.7 mg (95% CI, −18.4 to −11.0; $P < 0.001$) in the TAP block group (Table 2).

Subgroup analyses of TAP block studies using only landmark, US guidance, or inside the abdominal wall approaches are presented in Table 3. They similarly showed reductions in VAS scores and opioid consumption.

Transversus abdominal plane block vs epidural analgesia

Only three studies[41-43] addressed the comparison between TAP block and epidural anesthesia, and none of them showed any significant differences between the two techniques (Table 2). Only one RCT[43] investigated eight-hour pain score, and one trial[43] reported the 24-hr morphine consumption. It was not possible to perform subgroup analysis for this comparison.

Transversus abdominal plane block vs intrathecal morphine

Four studies examined the analgesic efficacy of TAP block in comparison with ITM in women scheduled for Cesarean delivery.[44-47] Use of ITM also reduced VAS score by 0.7 (95% CI, 0.3 to 1.1; $P = 0.001$) at six hours. Only one trial[45] evaluated the 12-hr pain score. All four trials investigated 24-hr pain scores; there was no statistical difference in the VAS scores obtained using ITM *vs* TAP block (Table 2). Intrathecal morphine, however, showed significantly reduced opioid consumption[44,46,47] by 7.7 mg (95% CI, −1.9 to −13.5; $P = 0.009$) in comparison with TAP block (Table 2). It was not possible to perform subgroup analysis for this comparison.

Transversus abdominal plane block vs ilioinguinal/iliohypogastric nerve block

We identified only two articles comparing TAP block with IIN block. In one study,[48] 273 adults scheduled for

Table 1 Characteristics of eligible studies ($n = 51$)

Characteristics	*n*	Characteristics	*n*
Age		Postoperative analgesia regimen	
Adults[17-20,22-49,51-53,55-64,66]	46	Intravenous morphine[18,20,30,31,34,39,45,48,49,52,55,63]	12
Pediatrics[20,49,53,64,69]	5	PCA morphine[19-21,23,25-29,35-37,39,41,43,46,47,51,54,60,62,65,69]	23
ASA score:		PCA fentanyl[38]	1
I-III[16-18,20-24,26-30,32,34,35,37-44,46-58,62-65,69]	43	NSAIDs[16,17,20-22,28,29,31,32,41,44,45,47-49,52,56-58,61,62]	21
Not reported[19,25,33,36,45,59-61]	8	Acetaminophen[17,20,22,25,26,28,30,31,34,36,41,44,45,47-49,51-53,56-60,62-65,69]	46
Type of surgery		TAP block technique	
Cesarean delivery[22,24,27,28,34,35,44-47,56,57]	12	US[22,23,26,27,32-46,48-53,55-57,59-65,69]	36
Gynecological procedures[17,21,26,32,50,51,54,58-61]	11	Landmark[19-21,24,25,28-31,47,54,58]	12
Cholecystectomy[52,55]	2	From inside the abdominal wall[16-18]	3
Appendectomy[20,30,62,69]	4	Type of block	
Inguinal hernia repair[30,31,39,48,49,53]	6	Single injections[16-38,40,43-50,52-65,69]	47
Bariatric surgery[33,37,63]	3	Continuous[39,41,42,51]	4
Liver resection[38,42]	2	Site of injection	
Gastrectomy[43]	1	Bilateral[16-19,21-24,26-29,32-38,41-47,50-52,54,56-61,63_65]	40
Urological surgery[19,23,25,40,64,65]	6	Unilateral[20,25,30,31,39,48,49,53,55,62,69]	11
Bowel resection[16,29,36,41]	4	Timing of the bock	
Comparator Group		Before surgery[17-21,23,25,26,29,30,32,36,38-40,43,48-50,52-55,59,62-65,69]	29
TAP *vs* placebo[16-40,56-65,69]	36	End of surgery[16,24,27,28,31,33-35,37,41,42,44-47,51,56-61]	22
TAP *vs* epidural[41-43]	3	Jadad score	
TAP *vs* ITM[44-47]	4	5[23,24,45,57,59,60,63,65]	8
TAP *vs* IIN[48,49]	2	4[16-22,25,26,28,29,31,33,35,36,47,48,50,52-54,56,58,62]	24
TAP *vs* local infiltration[50-55]	6	3[27,30,32,34,37-44,46,49,51,55,61,64,69]	19
Anesthesia technique		Other outcomes investigated	
General[16-69]	40	PONV[16,19-23,25-29,32,34-36,38-48,50-53,56,57,59,60,62-65,69]	39
Spinal[22,27,28,31,34,44-47,56,57]	11	Sedation[16,19-21,25-30,32-35,38,39,43-47,50,51,54,56,60,65,69]	28

ASA = American Society of Anesthesiologists; IIN = ilioinguinal/iliohypogastric nerve block; ITM = intrathecal morphine; NSAIDs = non-steroidal anti-inflammatory drugs; PCA = patient-controlled analgesia; PONV = postoperative nausea and vomiting; TAP = transversus abdominal plane block; US = ultrasound

inguinal hernia repair were randomly allocated to receive either US-guided TAP block or IIN block by a loss-of-resistance technique. Patients who received TAP block expressed significantly less pain at 12 hr ($P = 0.001$) and 24 hr ($P = 0.013$). Pain scores after the first 24 hr were similar in both groups. Postoperative morphine requirements were lower during the first 24 hr after surgery in the TAP block group ($P = 0.030$). The other study involving 41 children[49] found a higher number of patients reporting pain in the TAP block group *vs* the IIN group (76% *vs* 45%, respectively; $P = 0.040$) and a higher rate of analgesic consumption (62% *vs* 30%, respectively; $P = 0.037$).

Transversus abdominal plane block vs local infiltration

Six studies[50-55] investigated the efficacy of TAP block *vs* local anesthetic infiltration at the wound site. Compared with local infiltration, TAP block significantly reduced the six-hour VAS pain score[50,51,54] by 1.4 (95% CI, −2.2 to −0.6; $P < 0.001$); however, this difference was not significant at 12 hr[52,53] and 24 hr[51-53,55] (Table 2). The TAP block significantly reduced 24-hr morphine consumption by 5.0 mg (95% CI, −9.5 to −0.5; $P = 0.004$) (Table 2). It was not possible to perform subgroup analysis for this comparison.

Transversus abdominal plane block for Cesarean delivery

Twelve studies[22,24,27,28,34,35,44-47,56,57] evaluated the use of TAP block for Cesarean delivery. Nine trials[22,24,28,29,34,35,44,46,47] reported the six-hour pain score and six RCTs[22,24,28,34,35,47] investigated the 12-hr pain score. Compared with the control group, the overall analysis showed that the TAP block did not reduce VAS scores at six hour but reduced the VAS score by 1.5 (−2.3

Table 2 Summary of visual analogue pain score differences and differences in opioid consumption in patients receiving TAP block

Comparison	Pain / Opioids	Time	*n* of studies involved	Mean difference	95% CI	*P* value	I^2	Quality of the evidence (GRADE)
TAP block *vs* Placebo	Pain	6 hr	23	−1.37	−1.94 to −0.81	$P < 0.001$	0.94	moderate +++
TAP block *vs* Placebo	Pain	12 hr	18	−2.04	−2.72 to −1.37	$P < 0.001$	0.94	moderate +++
TAP block *vs* Placebo	Pain	24 hr	33	−1.17	−1.58 to −0.75	$P < 0.001$	0.93	moderate +++
TAP block *vs* Placebo	Opioids	24 hr	28	−14.68	−18.40 to −10.95	$P < 0.001$	0.99	moderate +++
TAP block *vs* Epidural	Pain	6 hr	2	+0.59	−0.57 to 1.75	$P = 0.32$	0.89	very low +
TAP block *vs* Epidural	Pain	24 hr	3	+1.29	−0.61 to 3.18	$P = 0.18$	0.97	very low +
TAP block *vs* ITM	Pain	6 hr	3	+0.69	0.28 to 1.11	$P = 0.001$	0.40	moderate +++
TAP block *vs* ITM	Pain	24 hr	4	+0.45	−0.06 to 0.95	$P = 0.08$	0.69	moderate +++
TAP block *vs* ITM	Opioids	24 hr	3	+7.67	1.89 to 13.45	$P = 0.009$	0.86	high ++++
TAP block *vs* LI	Pain	6 hr	3	−1.39	−2.20 to −0.57	$P < 0.001$	0.78	low ++
TAP block *vs* LI	Pain	12 hr	2	−2.94	−7.63 to 1.76	$P = 0.22$	0.99	low ++
TAP block *vs* LI	Pain	24 hr	4	−0.75	−2.23 to 0.73	$P = 0.32$	0.96	low ++
TAP block *vs* LI	Opioids	24 hr	3	−4.96	−9.45 to −0.48	$P = 0.004$	0.82	low ++
TAP block for CD	Pain	6 hr	9	−0.71	−1.54 to 0.12	$P = 0.09$	0.94	moderate +++
TAP block for CD	Pain	12 hr	6	−1.50	−2.33 to −0.66	$P < 0.001$	0.91	high ++++
TAP block for CD	Pain	24 hr	12	−0.18	−0.57 to 0.21	$P = 0.37$	0.83	moderate +++
TAP block for CD	Opioids	24 hr	11	−10.1	−17.35 to −2.82	$P = 0.006$	0.99	high ++++
TAP block for GS	Pain	6 hr	7	−1.18	−1.75 to −0.62	$P < 0.001$	0.79	moderate +++
TAP block for GS	Pain	12 hr	3	−1.13	−1.95 to −0.31	$P = 0.007$	0.80	moderate +++
TAP block for GS	Pain	24 hr	11	−1.13	−2.06 to −0.21	$P < 0.001$	0.96	moderate +++
TAP block for GS	Opioids	24 hr	8	−5.86	−8.60 to −3.10	$P < 0.001$	0.81	moderate +++
TAP block for AS	Pain	6 hr	6	−0.04	−1.35 to 1.27	$P = 0.95$	0.96	low ++
TAP block for AS	Pain	12 hr	4	−1.90	−4.21 to 0.41	$P = 0.11$	0.98	low ++
TAP block for AS	Pain	24 hr	8	−0.83	−2.05 to 0.39	$P = 0.18$	0.97	low ++
TAP block for AS	Opioids	24 hr	6	−14.67	−37.78 to 8.43	$P = 0.21$	0.99	moderate +++
TAP block for App/IS	Pain	6 hr	4	−2.49	−4.70 to −1.17	$P = 0.001$	0.94	moderate +++
TAP block for App/IS	Pain	12 hr	5	−3.92	−4.98 to −2.86	$P < 0.001$	0.88	moderate +++
TAP block for App/IS	Pain	24 hr	6	−1.67	−2.38 to −0.96	$P < 0.001$	0.89	low ++
TAP block for App/IS	Opioids	24 hr	3	−20.37	−29.70 to −11.05	$P < 0.001$	0.77	moderate +++
TAP block for BS	Pain	6 hr	2	−0.91	−1.33 to −0.49	$P < 0.001$	0.16	moderate +++
TAP block for BS	Pain	12 hr	2	−1.07	−1.58 to −0.56	$P < 0.001$	0.36	moderate +++
TAP block for BS	Pain	24 hr	3	−0.55	−2.08 to 0.98	$P = 0.48$	0.95	low ++
TAP block for BS	Opioids	24 hr	3	−3.80	−5.48 to −2.17	$P < 0.001$	0.33	moderate +++
TAP block for Urol.S	Pain	6 hr	3	−0.04	−0.85 to 0.78	$P = 0.93$	0.76	low ++
TAP block for Urol.S	Pain	12 hr	3	−2.59	−5.91 to 0.74	$P = 0.13$	0.97	low ++
TAP block for Urol.S	Pain	24 hr	5	−0.89	−2.05 to 0.27	$P = 0.13$	0.93	low ++
TAP block for Urol.S	Opioids	24 hr	4	−14.20	−30.59 to 2.18	$P = 0.09$	0.99	low ++

App/IS = appendectomy /inguinal surgery; AS = abdominal surgery; BS = bariatric surgery; CD = Cesarean delivery; CI = confidence interval; GS = gynecological surgery; I^2 = heterogeneity; ITM = intrathecal morphine; LI = local infiltration; TAP = transversus abdominal plane block; Urol S = urological surgery

to −0.7; $P < 0.001$) at 12 hr (Fig. 4). All the studies reported the 24-hr pain score, and 11 trials documented the 24-hr morphine consumption.[22,24,27,29,34,35,44,46,47,56,57] Transversus abdominal plane block did not significantly reduce the pain score (Table 2) at 24 hr but significantly reduced the mean 24-hr opioid consumption by 10 mg (95% CI, −17.4 to −2.8; $P = 0.006$) compared with the control group (Table 2). The US-guided and landmark subgroup analyses for Cesarean delivery studies are presented in Table 3.

Table 3 Summary of the visual analogue pain score results and results in opioid consumption in the subgroup analysis

Comparison	Pain / Opioids	Time	Subgroups	*n* of studies involved	Mean difference	95% CI	*P* value	I^2	Quality of the evidence (GRADE)
TAP block *vs* Placebo	Pain	6 hr	US	12	−0.92	−1.66 to −0.18	$P = 0.01$	0.94	moderate +++
TAP block *vs* Placebo	Pain	6 hr	Landmark	9	−2.07	−3.20 to −0.93	$P < 0.001$	0.95	moderate +++
TAP block *vs* Placebo	Pain	6 hr	IAW	2	−1.06	−1.54 to −0.59	$P < 0.001$	0.00	moderate +++
TAP block *vs* Placebo	Pain	12 hr	US	9	−2.13	−3.13 to −1.12	$P < 0.001$	0.95	moderate +++
TAP block *vs* Placebo	Pain	12 hr	Landmark	7	−2.15	−3.39 to −0.91	$P < 0.001$	0.95	moderate +++
TAP block *vs* Placebo	Pain	12 hr	IAW	2	−1.42	−2.44 to −0.41	$P < 0.001$	0.74	moderate +++
TAP block *vs* Placebo	Pain	24 hr	US	22	−1.04	−1.53 to −0.54	$P < 0.001$	0.93	moderate +++
TAP block *vs* Placebo	Pain	24 hr	Landmark	9	−1.51	−2.36 to −0.67	$P < 0.001$	0.94	moderate +++
TAP block *vs* Placebo	Pain	24 hr	IAW	2	−0.94	−1.51 to −0.36	$P = 0.001$	0.33	moderate +++
TAP block *vs* Placebo	Opioids	24 hr	US	20	−12.93	−17.58 to −8.28	$P < 0.001$	0.99	moderate +++
TAP block *vs* Placebo	Opioids	24 hr	Landmark	6	−23.83	−39.5 to −8.16	$P = 0.003$	0.99	moderate +++
TAP block *vs* Placebo	Opioids	24 hr	IAW	2	−7.61	−14.57 to −0.65	$P = 0.03$	0.89	moderate +++
TAP block for CD	Pain	6 hr	US	6	−0.39	−1.09 to 0.30	$P = 0.27$	0.90	moderate +++
TAP block for CD	Pain	6 hr	Landmark	3	−1.35	−3.98 to 1.29	$P = 0.32$	0.97	moderate +++
TAP block for CD	Pain	12 hr	US	4	−1.30	−2.40 to −0.20	$P = 0.02$	0.93	high ++++
TAP block for CD	Pain	12 hr	Landmark	2	−1.92	−2.40 to −1.43	$P < 0.001$	0.00	high ++++
TAP block for CD	Pain	24 hr	US	9	−0.11	−0.42 to 0.21	$P = 0.5$	0.68	moderate +++
TAP block for CD	Pain	24 hr	Landmark	3	−0.33	−1.91 to 1.25	$P = 0.68$	0.95	moderate +++
TAP block for CD	Opioids	24 hr	US	8	−9.31	−17.43 to −1.19	$P < 0.001$	0.99	high ++++
TAP block for CD	Opioids	24 hr	Landmark	3	−11.91	−39.31 to −15.48	$P < 0.001$	0.98	moderate +++
TAP block for App/IS	Pain	12 hr	US	2	−4.74	−6.72 to −2.76	$P < 0.001$	0.86	moderate +++
TAP block for App/IS	Pain	12 hr	Landmark	3	−3.43	−5.10 to −1.75	$P < 0.001$	0.88	moderate +++
TAP block for App/IS	Pain	24 hr	US	3	−2.48	−4.10 to −0.87	$P = 0.003$	0.94	moderate +++
TAP block for App/IS	Pain	24 hr	Landmark	3	−0.94	−1.55 to −0.34	$P < 0.001$	0.65	moderate +++

App/IS = appendectomy /inguinal surgery; CD = Cesarean delivery; CI = confidence interval; I^2 = heterogeneity; IAW = inside abdominal wall; TAP = transversus abdominal plane block; US = ultrasound

Transversus abdominal plane block in gynecological surgery

Eleven studies[17,21,26,32,50,51,54,58-61] evaluated the efficacy of TAP block in gynecological surgery. Compared with the control group, TAP block reduced the six-hour pain score[17,21,26,32,50,51,54] by 1.2 (95% CI, −1.8 to −0.6; $P < 0.001$), the 12-hr pain score[17,21,51] by 1.1 (95% CI, −2.0 to −0.3; $P = 0.007$), and the 24-hr pain score by 1.1 (95% CI, −2.1 to −0.2; $P < 0.001$). The TAP block also reduced 24-hr morphine consumption[17,21,26,50,54,60,61] by 5.9 mg (95% CI, −8.6 to −3.1; $P < 0.001$) (Fig. 5; Table 2). Only one trial[17] performed the TAP block from inside the abdominal wall; consequently, it was not possible to perform subgroup analysis for this comparison.

Transversus abdominal plane block in abdominal surgery

In the setting of major abdominal surgery, nine trials were retrieved.[16,29,36,38,40-43,52] Compared with the control group, TAP block showed no difference in reducing the six-hour pain score[16,29,36,38,41,43] (−0.1; 95% CI, −1.4 to 1.3; $P = 0.95$), 12-hr pain score[16,38,41,52] (1.9, 95% CI, −4.2 to 0.4; $P = 0.11$), 24-hr pain score[16,29,36,38,41-43,52] (−0.8; 95% CI, −2.0 to 0.4; $P = 0.18$), or 24-hr morphine consumption[16,29,36,38,43,52] (−14.7 mg; 95% CI, −37.8 to 8.4; $P = 0.21$) (Table 2). Only one trial[16] performed TAP block from inside the abdominal wall; consequently, it was not possible to perform subgroup analysis for this comparison.

Transversus abdominal plane block in appendectomy and inguinal surgery

In inguinal hernia surgery and appendectomy, compared with the control group, the overall analysis showed that the TAP block reduced the six-hour pain score[20,30,31,39] by 2.5 (95% CI, −4.7 to −1.2; $P = 0.001$) and the 12-hr pain score[20,30,31,39,48] by 3.9 (95% CI, −5.0 to −2.9; $P < 0.001$) (Fig. 6). Compared with the control group, the TAP block reduced the 24-hr pain score[20,30,31,39,48,62] by 1.7 (95% CI,

Study or Subgroup	TAP block Mean	TAP block SD	TAP block Total	Placebo Mean	Placebo SD	Placebo Total	Weight	Std. Mean Difference IV, Random, 95% CI
3.11.1 US								
Elkassabany 2013	3.2	0.75	16	5.5	0.5	15	3.9%	−3.49 [−4.66, −2.32]
Tammam 2014	1.5	0.5	22	4.25	0.75	23	4.0%	−4.22 [−5.30, −3.14]
Mahmoud 2014	5	0.75	25	3	0.25	25	4.2%	3.52 [2.61, 4.43]
Marais 2014	2.3	0.8	14	2.4	0.8	13	4.4%	−0.12 [−0.88, 0.63]
Wassef 2013	0.2	0.6	10	1.35	2.3	25	4.4%	−0.57 [−1.31, 0.18]
Shin 2011	2.6	2.5	16	4.1	2.4	16	4.4%	−0.60 [−1.31, 0.11]
Baaj 2010	1.2	0.8	20	2.2	0.8	20	4.4%	−1.23 [−1.91, −0.54]
Sriramka 2012	2.8	0.8	25	4.3	0.8	25	4.4%	−1.85 [−2.52, −1.18]
Tan 2012	0.75	0.75	20	1.1	0.75	20	4.5%	−0.46 [−1.09, 0.17]
Walter 2013	2.9	2.8	33	3.6	2.6	33	4.6%	−0.26 [−0.74, 0.23]
Costello 2009	0.9	0.2	47	1.2	0.3	39	4.6%	−1.19 [−1.65, −0.73]
Sinha 2013	1	0.5	50	2	1.25	50	4.6%	−1.04 [−1.46, −0.62]
Subtotal (95% CI)			**298**			**304**	**52.5%**	**−0.92 [−1.66, −0.18]**
Heterogeneity: Tau^2 = 1.56; Chi^2 = 170.22, df = 11 (P < 0.00001); I^2 = 94%								
Test for overall effect: Z = 2.45 (P = 0.01)								
3.11.2 Landmark								
McDonnell 2007	1.8	0.7	16	4.3	0.5	16	3.8%	−4.01 [−5.26, −2.75]
Salman 2013	1.3	0.8	32	5.3	0.8	32	4.1%	−4.94 [−5.95, −3.93]
Eslamian 2012	1.5	1	24	6	1.5	24	4.2%	−3.47 [−4.39, −2.55]
Aniskevich 2014	3	1.5	10	3.5	2.5	11	4.3%	−0.23 [−1.09, 0.63]
Carney 2008	1.9	0.9	24	3.8	0.75	26	4.4%	−2.27 [−2.99, −1.54]
Carney 2010	1.9	1.25	19	4.1	1.5	21	4.4%	−1.55 [−2.27, −0.84]
Melchisedec 2013	0	0.8	20	1	0.8	20	4.4%	−1.23 [−1.91, −0.54]
McDonnell 2008	1	0.75	25	3	1.25	25	4.4%	−1.91 [−2.59, −1.23]
Freir 2012	2.8	0.8	32	2.3	0.8	33	4.6%	0.62 [0.12, 1.12]
Subtotal (95% CI)			**202**			**208**	**38.7%**	**−2.07 [−3.20, −0.93]**
Heterogeneity: Tau^2 = 2.84; Chi^2 = 161.30, df = 8 (P < 0.00001); I^2 = 95%								
Test for overall effect: Z = 3.57 (P = 0.0004)								
3.11.3 From inside the abdominal wall								
Wijewardana 2014	2.8	0.9	22	3.7	0.7	18	4.4%	−1.08 [−1.75, −0.41]
Bharti 2011	2.5	0.75	20	3.3	0.75	20	4.4%	−1.05 [−1.71, −0.38]
Subtotal (95% CI)			**42**			**38**	**8.9%**	**−1.06 [−1.54, −0.59]**
Heterogeneity: Tau^2 = 0.00; Chi^2 = 0.01, df = 1 (P = 0.94); I^2 = 0%								
Test for overall effect: Z = 4.41 (P < 0.0001)								
Total (95% CI)			**542**			**550**	**100.0%**	**−1.37 [−1.94, −0.81]**
Heterogeneity: Tau^2 = 1.77; Chi^2 = 346.35, df = 22 (P < 0.00001); I^2 = 94%								
Test for overall effect: Z = 4.75 (P < 0.00001)								
Test for subgroup differences: Chi^2 = 3.01, df = 2 (P = 0.22), I^2 = 33.4%								

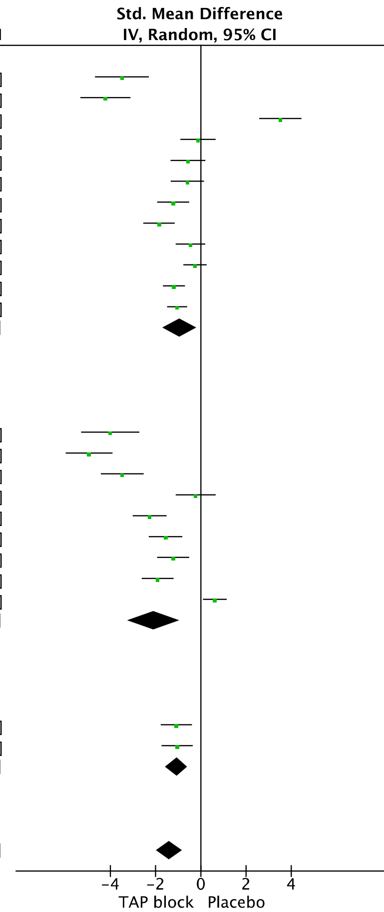

Fig. 2 Forest plot showing the six-hour pain score. The analgesic efficacy of transversus abdominal plane block (TAP) is evaluated in comparison with placebo. The sample size, mean, standard deviation (SD), mean difference, 95% confidence interval (CI), and heterogeneity are shown

−2.4 to −1.0; $P < 0.001$) and 24-hr morphine consumption[30,39,62] by 20.4 mg (95% CI, −29.7 to −11.1; $P < 0.001$) (Table 2).

The 12- and 24-hr US and landmark subanalyses are presented in Table 3. It was not possible to perform subgroup analysis for the six-hour pain score and the 24-hr morphine consumption.

Transversus abdominal plane block in bariatric surgery

There were three studies of TAP block in the setting of bariatric surgery.[33,37,63] All were laparoscopic procedures (single-port sleeve gastrectomy and gastric bypass surgery) studying the efficacy of TAP block compared with placebo. Transversus abdominal plane block reduced the six-hour pain score by 0.9 (95% CI, −1.3 to −0.5; $P < 0.001$) and the 12-hr pain score by 1.1 (95% CI, −1.6 to −0.6; $P < 0.001$).[33,37] All trials evaluated 24-hr pain scores and 24-hr morphine consumption. Transversus abdominal plane block did not reduce the 24-hr pain score (−0.6; 95% CI, −2.1 to 1.0; $P = 0.48$). In comparison with placebo, TAP block significantly reduced the 24-hr morphine consumption by 3.8 mg (95% CI, −5.5 to −2.2; $P < 0.001$) (Table 2). It was not possible to perform subgroup analysis for this comparison.

Transversus abdominal plane block in urologic surgery

In the setting of urologic surgery, including laparoscopic nephrectomy, radical prostatectomy and renal transplantation, we retrieved six articles.[19,23,25,40,64,65] Transversus abdominal plane block did not reduce six-hour,[19,23,25] 12-hr,[19,25,40] or 24-hr pain scores[19,23,25,40,65] (Table 2). In comparison with placebo, the effect of the TAP block on morphine consumption at 24 hr[19,23,25,40] was also not significant (−14.2 mg; 95% CI, −30.6 to 2.2; $P = 0.09$)

Discussion

This systematic review and meta-analysis focused on the efficacy of the TAP block for postoperative analgesia in a

Study or Subgroup	TAP block Mean	TAP block SD	TAP block Total	Placebo Mean	Placebo SD	Placebo Total	Weight	Std. Mean Difference IV, Random, 95% CI
2.11.1 US								
Aniskevich 2014	2.25	1.5	10	4.25	2.9	11	5.5%	−0.82 [−1.72, 0.08]
Costello 2009	1	0.25	47	1	0.2	49	5.9%	0.00 [−0.40, 0.40]
Mahmoud 2014	5	1	25	6	0.25	25	5.8%	−1.35 [−1.97, −0.73]
Sinha 2013	1	0.5	50	2	1	50	5.9%	−1.26 [−1.69, −0.82]
Soltani 2014	1	0.2	22	2.75	0.25	22	4.3%	−7.59 [−9.36, −5.83]
Sriramka 2012	2.1	0.8	25	4.2	0.8	25	5.6%	−2.58 [−3.35, −1.82]
Tammam 2014	1	0.5	22	4	0.5	23	4.8%	−5.89 [−7.30, −4.49]
Tan 2012	0.25	0.25	20	0.9	0.5	20	5.7%	−1.61 [−2.33, −0.89]
Wassef 2013	1	0.3	10	0.9	1.25	25	5.7%	0.09 [−0.64, 0.82]
Subtotal (95% CI)			**231**			**250**	**49.1%**	**−2.13 [−3.13, −1.12]**
Heterogeneity: $Tau^2 = 2.13$; $Chi^2 = 153.91$, df = 8 ($P < 0.00001$); $I^2 = 95\%$								
Test for overall effect: Z = 4.16 ($P < 0.0001$)								
2.11.2 Landmark								
Carney 2008	1.75	0.75	24	3.2	0.7	26	5.7%	−1.97 [−2.66, −1.28]
Carney 2010	1.25	1.25	19	3.9	1.4	21	5.6%	−1.95 [−2.72, −1.18]
Eslamian 2012	1.25	0.75	24	3	1	24	5.7%	−1.95 [−2.64, −1.25]
Freir 2012	2.3	0.8	32	1.9	0.8	33	5.9%	0.49 [−0.00, 0.99]
McDonnell 2008	0.6	0.7	25	2.2	1.3	25	5.8%	−1.51 [−2.14, −0.87]
Melchisedec 2013	0	0.8	32	3	0.8	20	5.4%	−3.69 [−4.62, −2.77]
Salman 2013	1.2	0.8	32	5	0.8	32	5.4%	−4.69 [−5.66, −3.72]
Subtotal (95% CI)			**188**			**181**	**39.5%**	**−2.15 [−3.39, −0.91]**
Heterogeneity: $Tau^2 = 2.66$; $Chi^2 = 130.25$, df = 6 ($P < 0.00001$); $I^2 = 95\%$								
Test for overall effect: Z = 3.40 (P = 0.0007)								
2.11.3 From inside the abdominal wall								
Bharti 2011	1	0.5	20	2	0.5	20	5.6%	−1.96 [−2.73, −1.19]
Wijewardana 2014	2.1	1	22	3	0.9	18	5.7%	−0.92 [−1.58, −0.26]
Subtotal (95% CI)			**42**			**38**	**11.4%**	**−1.42 [−2.44, −0.41]**
Heterogeneity: $Tau^2 = 0.41$; $Chi^2 = 4.05$, df = 1 (P = 0.04); $I^2 = 75\%$								
Test for overall effect: Z = 2.74 (P = 0.006)								
Total (95% CI)			**461**			**469**	**100.0%**	**−2.04 [−2.72, −1.37]**
Heterogeneity: $Tau^2 = 1.94$; $Chi^2 = 294.50$, df = 17 ($P < 0.00001$); $I^2 = 94\%$								
Test for overall effect: Z = 5.96 ($P < 0.00001$)								
Test for subgroup differences: $Chi^2 = 1.19$, df = 2 (P = 0.55), $I^2 = 0\%$								

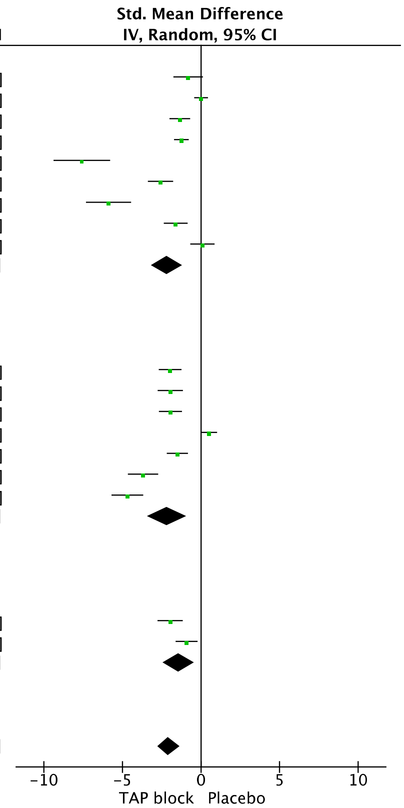

Fig. 3 Forest plot showing the 12-hr pain score. The analgesic efficacy of transversus abdominal plane block (TAP) is evaluated in comparison with placebo. The sample size, mean, standard deviation (SD), mean difference, 95% confidence interval (CI), and heterogeneity are shown

comprehensive group of abdominal surgical procedures. Compared with placebo, when TAP blocks are used for postoperative analgesia, the data show a significant reduction in pain scores at six, 12, and 24 hr as well as a reduction in 24-hr opioid consumption. Intrathecal morphine seems to decrease opioid consumption better than the TAP block while achieving similar pain scores. Transversus abdominal plane block is also able to decrease opioid consumption compared with local infiltration techniques. When compared with epidural analgesia and IIN blocks, it was not possible to draw a conclusion about the efficacy of TAP blocks due to the scarcity of published studies.

When analyzing the efficiency of TAP block pain control after different types of surgery, it seems most beneficial—in terms of both reduction in pain and opioid consumption—for gynecological surgery, bariatric surgery, and appendectomy and inguinal hernia surgery. It also reduces opioid consumption significantly after Cesarean delivery.

Even if statistically significant, a difference of < 1 point on a 0-10 VAS scale and a small (e.g., ≤ 5 mg) reduction in morphine consumption cannot be considered to have great clinical significance. Interestingly, this reduction varied from 4.9 mg (TAP block *vs* local infiltration) to 10.1 mg in Cesarean delivery and up to 20.4 mg in appendectomy and inguinal surgery (Table 2). Furthermore, we did not consider opioid-induced side effects (i.e., sedation, postoperative nausea and vomiting, respiratory depression, suppressed cough reflex), though a reduction in opioid consumption could lead to a significant clinical improvement in these side effects.

It is also important to underline that the large heterogeneity found might reduce the clinical significance of our results.

Our subgroup analyses on the comparison of the US- *vs* the landmark-guided technique did not observe a remarkable superiority of one technique over the other. Regardless of the numerous advantages of performing nerve block with US, in our view, the analgesic efficacy of the TAP block is influenced by several other factors, such as the type and dose of anesthetics used, the timing (before/after the surgery), and the approach (i.e., mid-axillary, subcostal, posterior).

Previously published meta-analyses reported similar results. Mishriky *et al.*[66] published a meta-analysis of nine RCTs investigating the efficacy of TAP block for pain control after Cesarean delivery. In that meta-analysis, the

Study or Subgroup	TAP block Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
2.10.1 US								
Costello 2009	1	0.25	47	1	0.2	49	17.7%	0.00 [−0.40, 0.40]
Kanazi 2010	1.8	1.5	29	3.8	2	28	17.1%	−1.12 [−1.68, −0.56]
Sriramka 2012	2.1	0.8	25	4.2	0.8	25	16.0%	−2.58 [−3.35, −1.82]
Tan 2012	0.25	0.25	20	0.9	0.5	20	16.3%	−1.61 [−2.33, −0.89]
Subtotal (95% CI)			**121**			**122**	**67.1%**	**−1.30 [−2.40, −0.20]**
Heterogeneity: Tau² = 1.16; Chi² = 42.19, df = 3 (P < 0.00001); I² = 93%								
Test for overall effect: Z = 2.31 (P = 0.02)								
2.10.2 Landmark technique								
Eslamian 2012	1.25	0.75	24	3	1	24	16.4%	−1.95 [−2.64, −1.25]
McDonnell 2008	0	0.7	25	2	1.3	25	16.5%	−1.89 [−2.56, −1.21]
Subtotal (95% CI)			**49**			**49**	**32.9%**	**−1.92 [−2.40, −1.43]**
Heterogeneity: Tau² = 0.00; Chi² = 0.02, df = 1 (P = 0.90); I² = 0%								
Test for overall effect: Z = 7.74 (P < 0.00001)								
Total (95% CI)			**170**			**171**	**100.0%**	**−1.50 [−2.33, −0.66]**
Heterogeneity: Tau² = 0.98; Chi² = 56.28, df = 5 (P < 0.00001); I² = 91%								
Test for overall effect: Z = 3.51 (P = 0.0005)								
Test for subgroup differences: Chi² = 1.01, df = 1 (P = 0.31), I² = 1.3%								

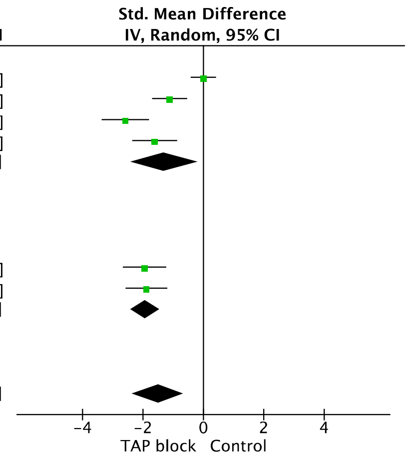

Fig. 4 Forest plot showing the 12-hr pain score. The analgesic efficacy of transversus abdominal plane block (TAP) is evaluated in Cesarean delivery. The control group received saline, no block or intrathecal morphine. The sample size, mean, standard deviation (SD), mean difference, 95% confidence interval (CI), and heterogeneity are shown

Study or Subgroup	TAP block Mean	SD	Total	Control Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Atim 2011	16.32	5.6	18	24.1	5.6	19	14.5%	−7.78 [−11.39, −4.17]
Carney 2008	21.1	12.7	24	39.6	15.7	26	7.5%	−18.50 [−26.39, −10.61]
De Oliveira 2011	14.37	3.12	21	17	2	23	18.2%	−2.63 [−4.19, −1.07]
Griffiths 2010	36	27.7	32	34	27.3	33	3.5%	2.00 [−11.37, 15.37]
Kane 2012	7.5	5.5	28	9	3	28	17.0%	−1.50 [−3.82, 0.82]
Marais 2014	12.9	8.9	14	25	12.1	13	7.3%	−12.10 [−20.16, −4.04]
Sivapurapu 2013	22.15	4.14	26	29.15	3.93	26	17.2%	−7.00 [−9.19, −4.81]
Wijewardana 2014	1	3.08	22	5	6.88	18	14.9%	−4.00 [−7.43, −0.57]
Total (95% CI)			**185**			**186**	**100.0%**	**−5.86 [−8.61, −3.10]**
Heterogeneity: Tau² = 10.25; Chi² = 36.25, df = 7 (P < 0.00001); I² = 81%								
Test for overall effect: Z = 4.16 (P < 0.0001)								

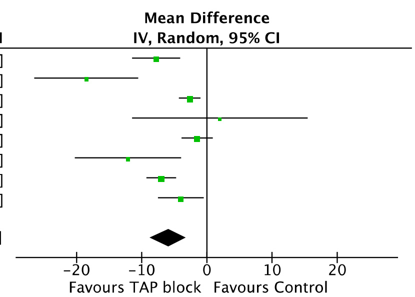

Fig. 5 Forest plot showing the 24-hr morphine consumption. The analgesic efficacy of transversus abdominal plane block (TAP) is evaluated in gynecological surgery. The control group received saline, no block or local infiltration. The sample size, mean, standard deviation (SD), mean difference, 95% confidence interval (CI), and heterogeneity are shown

Study or Subgroup	TAP block Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
2.9.1 US								
Aveline 2011	1.65	0.5	124	3.15	0.25	139	23.1%	−3.85 [−4.26, −3.44]
Tammam 2014	1	0.5	22	4	0.5	20	16.5%	−5.89 [−7.34, −4.43]
Subtotal (95% CI)			**146**			**159**	**39.5%**	**−4.74 [−6.72, −2.76]**
Heterogeneity: Tau² = 1.78; Chi² = 6.97, df = 1 (P = 0.008); I² = 86%								
Test for overall effect: Z = 4.70 (P < 0.00001)								
2.9.2 Landmark technique								
Carney 2010	1.25	1.25	19	3.9	1.37	21	21.2%	−1.98 [−2.75, −1.21]
Melchisedec 2013	0	0.8	20	3	0.8	20	19.3%	−3.68 [−4.73, −2.62]
Salman 2013	1.2	0.8	32	5	0.8	32	19.9%	−4.69 [−5.66, −3.72]
Subtotal (95% CI)			**71**			**73**	**60.5%**	**−3.43 [−5.10, −1.75]**
Heterogeneity: Tau² = 1.95; Chi² = 19.55, df = 2 (P < 0.0001); I² = 90%								
Test for overall effect: Z = 4.02 (P < 0.0001)								
Total (95% CI)			**217**			**232**	**100.0%**	**−3.92 [−4.98, −2.86]**
Heterogeneity: Tau² = 1.22; Chi² = 32.46, df = 4 (P < 0.00001); I² = 88%								
Test for overall effect: Z = 7.26 (P < 0.00001)								
Test for subgroup differences: Chi² = 1.00, df = 1 (P = 0.32), I² = 0%								

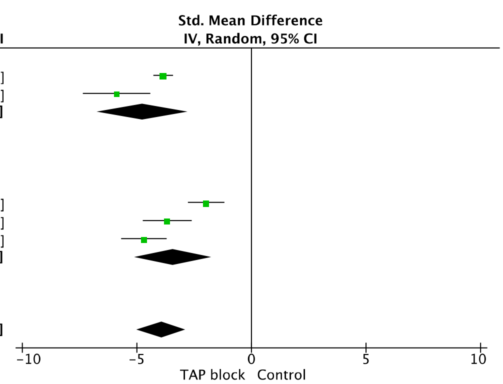

Fig. 6 Forest plot showing the 12-hr pain score. The analgesic efficacy of transversus abdominal plane block (TAP) is evaluated in appendectomy and inguinal surgery. The control group received saline, no block or ilioinguinal nerve block. The sample size, mean, standard deviation (SD), mean difference, 95% confidence interval (CI), and heterogeneity are shown

authors performed subgroup analysis; they calculated the confidence interval for articles comparing TAP block with placebo separately from the confidence interval for trials comparing TAP block with ITM. The authors concluded that TAP block improved postoperative analgesia significantly in women undergoing Cesarean delivery who did not receive ITM; whereas, they did not find significant improvement in pain control and morphine consumption in patients who received ITM. In our analysis, we obtained similar results. Taken together, this suggests that TAP block might play an important role in patients with contraindications to opioids.

A strength of our meta-analysis compared with prior meta-analyses studying TAP block[7,8,66] is that prior ones reported a small number of studies limited to specific surgical procedures. Given the increasing number of TAP block studies appearing in the literature, we performed a systematic review and meta-analysis across a wider range of studies. Nevertheless, our meta-analysis does have several limitations. First, it was not possible to obtain data from all the trials included. Some studies used non-opioid drugs for postoperative pain management; others did not collect data at 24 hr after surgery, and others did not use the VAS score to report pain. Second, the overwhelming majority of studies retrieved focused on the comparison of TAP block with placebo. Few studies focused on the comparison with other anesthetic techniques (e.g., epidural analgesia). There is still a need for more studies comparing TAP block with other analgesic techniques in a large cohort of patients.

An additional limitation is that we observed a high degree of heterogeneity between the studies. This likely reflects the different types of surgical procedures, differences in the choice of local anesthetic used and in the dose administered. Similarly, the differences among the patients (e.g., age, comorbidities) and interventions (e.g., type of block, timing, postoperative analgesia) may have played an important role in increasing heterogeneity. Both single-injection and continuous TAP blocks provide postoperative analgesia; however,[67] the two techniques may have had a different impact on the postoperative VAS score. Transversus abdominal plane block is an operator-dependent procedure that can be performed following different approaches. Since Rafi's classic description,[1] a growing number of studies appeared in the literature showing different new techniques to perform the TAP block (e.g., oblique subcostal approach).[68] As suggested in some cadaveric studies,[2-4] the spread of local anesthetic is influenced by the approach used. Moreover, a 2013 systematic review and meta-analysis[69] showed that the posterior TAP block technique determined a greater reduction in opioid consumption and in rest and dynamic pain scores compared with the lateral approaches. Lastly, performing the TAP block before the procedure (i.e., preemptive analgesia) or at the end of the surgery may have had an important clinical impact on the analgesic control.

During the conduct of this review and meta-analysis, we identified some areas for future research. It would be useful to continue to investigate the efficacy of TAP blocks for pain management in comparison with epidural and IIN nerve blocks. Future studies could also focus on the influence of timing of the block and type and concentration of local anesthetic drug administered (i.e., dose-ranging studies).

Based on our findings, the best recommendation (i.e., improved pain score and decreased opioid consumption) for using TAP block for postoperative analgesia is in gynecological procedures, bariatric surgery, appendectomy, and inguinal hernia repair.

It can also be recommended for Cesarean delivery (i.e., because of a decrease in opioid consumption). There is as yet no valid recommendation for its potential to decrease pain or opioid consumption in abdominal surgery in general or urological procedures.

Even if TAP block is not as effective as ITM or epidural analgesia, TAP block might be used to provide analgesia when neuraxial techniques or opioids are contraindicated. Future RCTs are needed to compare the efficacy of TAP block with epidural or IIL nerve block.

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