A comparison of pain scores and medication use in patients undergoing single-bundle or double-bundle anterior cruciate ligament reconstruction

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A summary of the findings of this study was presented at the Canadian Orthopaedic Association Annual Meeting, Ottawa, 2012.

Accepted for publication
Sept. 6, 2013

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DOI: 10.1503/cjs.018612

Background: No gold standard exists for the management of postoperative pain following anterior cruciate ligament reconstruction (ACLR). We compared the pain scores and medication use of patients undergoing single-bundle (SB) or double-bundle (DB) ACLR in the acute postoperative period. Pain and medication use was also analyzed for spinal versus general anesthesia approaches within both surgery types.

Methods: We assessed 2 separate cohorts of primary ACLR patients, SB and DB, for 14 days postoperatively. We used a standard logbook to record self-reported pain scores and medication use. Pain was assessed using a 100 mm visual analogue scale (VAS). Medications were divided into 3 categories: oral opioids, oral nonsteroidal anti-inflammatories and acetaminophen.

Results: A total of 88 patients undergoing SB and 41 undergoing DB ACLR were included in the study. We found no significant difference in VAS pain scores between the cohorts. Despite similar VAS pain scores, the DB cohort consumed significantly more opioid and analgesia medication ($p = 0.011$). Patients who underwent DB with spinal anesthesia experienced significantly less pain over the initial 14-day postoperative period than those who received general anesthesia ($p < 0.001$).

Conclusion: Adequate pain relief was provided to all ACLR patients in the initial postoperative period. Patients in the DB cohort experienced more pain, as evidenced by the significant difference in consumption of opioids and acetaminophen, than the SB cohort. Patients who underwent spinal anesthesia experienced less pain in the acute postoperative period than those who received general anesthesia.

Contexte : Il n'existe pas de norme établie pour la prise en charge de la douleur postopératoire après la reconstruction du ligament croisé antérieur (RLCA). Nous avons comparé les scores de douleur et le recours aux analgésiques chez des patients soumis à une RLCA simple faisceau (SF) ou double faisceau (DF) durant la période postopératoire immédiate. La douleur et l'utilisation des analgésiques ont aussi été analysées en rapport avec l'anesthésie utilisée, rachidienne ou générale, dans les 2 types de chirurgie.

Méthodes : Nous avons évalué 2 cohortes distinctes de patients soumis à une RLCA primaire, SF et DF, pendant les 14 premiers jours postopératoires. Les patients ont consigné leurs scores de douleur et leur utilisation d'analgésiques dans des carnets de bord standard. La douleur était évaluée au moyen d'une échelle analogique visuelle (ÉAV) de 100 mm. Les analgésiques étaient regroupés sous 3 catégories, soit opiacés oraux, anti-inflammatoires non stéroïdiens oraux et acétaminophène.

Résultats : En tout, 88 patients soumis à une RLCA SF et 41 à une RLCA DF ont été inclus dans l'étude. Nous n'avons observé aucune différence significative quant au score de douleur à l'ÉAV entre les cohortes. Malgré des scores de douleur similaires à l'ÉAV, la cohorte soumise à l'intervention DF a utilisé significativement plus d'opiacés et autres analgésiques ($p = 0.011$). Comparativement aux patients sous anesthésie générale, les patients soumis à l'intervention DF sous anesthésie rachidienne ont éprouvé significativement moins de douleur au cours des 14 premiers jours postopératoires ($p < 0.001$).

Conclusion : Tous les patients qui ont subi une RLCA ont obtenu un soulagement adéquat de leur douleur durant la période postopératoire initiale. Les patients de la cohorte DF ont éprouvé davantage de douleur, comme en témoigne la différence significative de consommation d'opiacés et d'acétaminophène comparativement à la cohorte SF. Les patients qui ont subi une anesthésie rachidienne ont éprouvé moins de douleur pendant la période postopératoire immédiate, comparativement aux patients sous anesthésie générale.

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The anterior cruciate ligament (ACL) is the most commonly injured knee ligament, with approximately 200 000 ruptures annually in the United States.[1] Two common surgical approaches to treat the ACL-deficient knee are the single-bundle (SB) and anatomic double-bundle (DB) reconstruction methods. To our knowledge, no studies have been published to date comparing pain and medication use for the SB and DB ACL reconstruction (ACLR) procedures or comparing pain scores in the acute postoperative period for spinal versus general anesthesia approaches for these procedures.

No gold standard exists for the management of postoperative pain following ACLR.[2] Postoperative pain is often overlooked even though prevention and effective relief of acute pain can improve clinical outcomes, avoid clinical complications, save health care resources and improve quality of life.[3] Managing postoperative pain is also important because research has shown that early control of pain can assist with managing its evolution and development.[4] Previous studies have analyzed the effects of pain and rehabilitation for SB ACLR surgery and reported that postoperative patients who were unable to perform straight leg raises had significantly higher pain scores than patients who were able to perform straight leg raises.[5] These findings suggest that pain may inhibit function, limit early rehabilitation and delay recovery in the long-term.[5]

The purpose of this quality assurance study was to compare postoperative pain scores and medication use between patients undergoing SB or DB ACLR and to determine if there was a difference in pain scores between patients receiving spinal anesthesia and those receiving general anesthesia for either SB or DB ACLR.

Methods

We followed patients undergoing primary ACLR for 14 days postoperatively. All patients were assessed by 1 of 3 surgeons (L.A.H., S.M.H., G.M.B.) at the Banff Sport Medicine Clinic. The diagnosis of ACL deficiency was confirmed via a thorough history and clinical examination, including diagnostic imaging as necessary. Reconstruction surgery options were discussed with each patient. Patients considered for DB ACLR included those with a grade 3 pivot shift, athletes involved in high-demand pivoting sports and individuals likely to have a large ACL footprint. The final decision was made intraoperatively, as patients with inadequate-sized tendons or footprint areas were not suitable for DB ACLR.

The patients who underwent SB ACLR had previously been enrolled in a double-blind randomized controlled trial (RCT) in which pain and medication use was recorded for 14 days postoperatively (15 d in total).[6] We consecutively enrolled the patients in the DB ACLR group in a case series and recorded pain and medication use in the same manner as the RCT to assess appropriate provision of postoperative analgesia. We excluded patients undergoing revision surgery or reconstruction with allograft from our study.

All patients in the SB cohort received a primary anatomic ACLR with hamstring tendon autograft. The DB autograft ACLR was performed, as described by Hensler and colleagues,[7] with semitendinosus and gracilis tendons using a 2-tunnel technique. All surgeries were conducted under spinal or general anesthesia after consultation among the surgeon, patient and anesthesiologist.

At the time of discharge, all patients in the SB and DB ACLR cohorts were provided with a prescription for either 30 Percocet tablets (325 mg acetaminophen plus 5 mg oxycodone) or 30 Tylenol No. 3 tablets (325 mg acetaminophen plus 30 mg codeine) along with 30 Naproxen tablets (500 mg naprosyn). Patients were advised to take the Percocet or Tylenol No. 3 every 4 hours as required for pain management and the Naproxen twice daily (morning and evening) to help reduce the swelling and inflammation. Patients were also advised they could use regular Tylenol (acetaminophen 325 mg) for pain management.

Pain and medication logbook

Visual analogue scale (VAS) pain scores and medication use were recorded by each patient in a standard logbook

Table 1. Single-bundle versus double-bundle self-reported mean VAS pain scores

Postoperative time	Group; mean ± SD VAS score*		Mean difference† (95% CI)	*p* value
	Single-bundle, *n* = 88	Double-bundle, *n* = 41		
1 h	2.0 ± 2.2	36.1 ± 29.6	–34.1 (–40.3 to –27.8)	< 0.001
Day 0, pm	29.6 ± 22.1	32.4 ± 21.3	–2.8 (–11.0 to 5.4)	0.50
Day 1, am	31.2 ± 25.2	34.5 ± 20.2	–3.3 (–12.2 to 5.6)	0.46
Day 1, pm	43.7 ± 23.0	49.3 ± 21.0	–5.6 (–14.0 to 2.8)	0.19
Day 2, am	38.0 ± 24.2	43.7 ± 24.3	–5.7 (–14.8 to 3.4)	0.22
Day 2, pm	33.8 ± 21.9	34.8 ± 20.2	–1.0 (–9.0 to 7.0)	0.81
Day 7	27.1 ± 21.5	26.2 ± 19.3	0.9 (–6.9 to 8.7)	0.82
Day 14	13.4 ± 15.6	12.2 ± 11.4	1.2 (–4.2 to 6.6)	0.66

CI = confidence interval; SD = standard deviation; VAS = visual analogue scale.
*VAS score: no pain = 0; worst pain possible = 100.
†Single-bundle minus double-bundle.

from the day of surgery through to the evening of postoperative day 14. Patients received the logbook along with detailed verbal and written instructions the morning of surgery. Pain scores were recorded on a 100 mm VAS, on which 0 corresponded to no pain and 100 corresponded to the worst pain possible. A nurse documented the initial pain VAS entry 1 hour after the procedure, then patients independently completed all subsequent pain score entries. The scores were recorded twice daily (8 am and 8 pm) from the day of surgery until the evening of postoperative day 2 and then daily (5 pm) on postoperative days 3–14.

Medication use, including amount and type, was recorded by each patient in their logbooks from the day of surgery until postoperative day 14. Medications were divided into 3 categories: oral opioids (i.e., Percocet and Tylenol No. 3), oral nonsteroidal anti-inflammatory drugs (NSAID; i.e., naprosyn, ibuprofen) and acetaminophen. Approximately 3 weeks after surgery each patient was assessed by their respective surgeons using a standardized postoperative examination, and patients returned their logbooks.

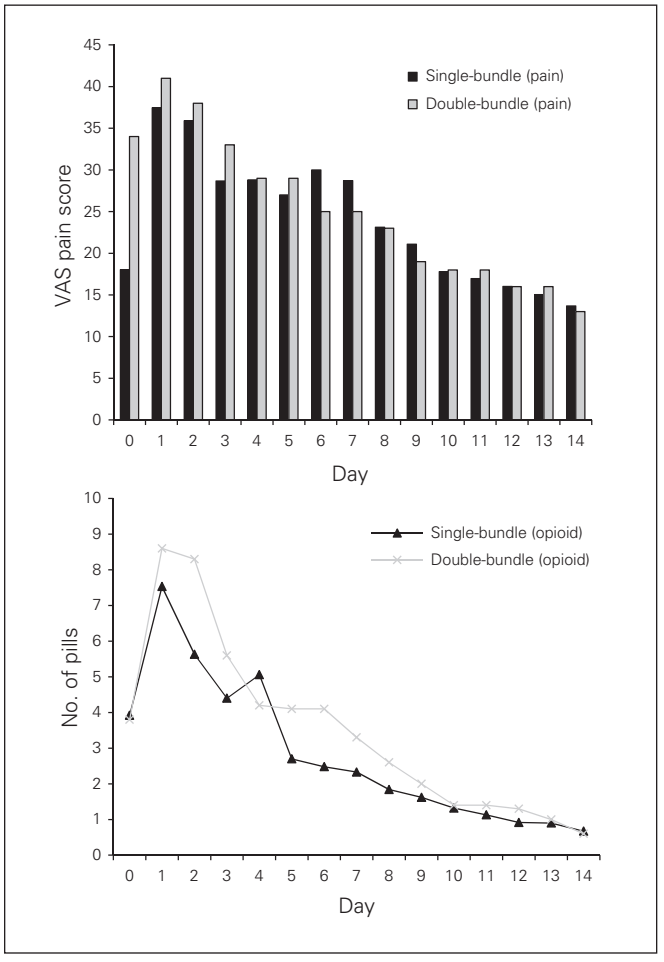

Fig. 1. Single-bundle versus double-bundle visual analogue scale (VAS) pain scores and mean opioid use over the 15-day period.

Statistical analysis

Data were entered and analyzed using SPSS software version 17 (SPSS Inc.). We performed unpaired *t* tests to compare pain scores between the SB and DB cohorts and the spinal and general anesthesia groups and to compare the duration of surgery between the SB and DB procedures. We compared medication use between the groups over the total 15-day period using a paired *t* test. All tests of significance were 2-sided, and we considered results to be significant at $p < 0.05$. For pain scores, we calculated 95% confidence intervals (CIs) of the difference of the mean.

RESULTS

Participants

In all, we followed 129 patients who underwent primary ACLR. A total of 88 patients (53 men, 35 women) underwent SB ACLR, and all of them returned pain and medication logbooks. The mean age of the SB cohort was 28.6 ± 5.8 years. A total of 67 patients underwent DB ACLR. Of these 67 patients, 26 underwent revision surgery or reconstruction with allograft and were not included in this study. All 41 eligible patients returned their logbooks. The mean age of the DB cohort was 24.7 ± 9.8 years. The DB operation was significantly longer than the SB procedure (74.8 ± 12.1 min v. 57 ± 11.8 min, $p < 0.001$).

Single-bundle versus double-bundle VAS pain scores

There was a significant difference in pain at 1 hour postsurgery, with a lower mean pain score in the SB cohort than the DB cohort (2.04 ± 2.2 v. 36.1 ± 29.6, $p < 0.001$; Table 1). For both procedures, VAS pain scores peaked at postoperative day 1 (8 pm), with a mean score of 43.7 ± 23 in the SB cohort and 49.3 ± 21 in the DB cohort. Afterwards, there was a decrease in VAS pain scores through postoperative day 14 for both cohorts (Fig. 1). Over the entire 15-day period, the average VAS pain score in the DB cohort was 25.1 ± 8.6 compared with 23.9 ± 7.6 in the SB cohort, but this difference did not reach statistical significance. There were no significant differences in mean pain scores based on sex.

Single-bundle versus double-bundle medication use

Opioid use over the 15-day period peaked at postoperative day 1 for both procedures, with the SB cohort taking fewer pills than the DB cohort (mean 7.5 ± 3.0 v. 8.6 ± 2.5, $p = 0.043$). Afterwards, opioid use steadily declined for both procedures, with the lowest consumption

observed on postoperative day 14 (Fig. 1). Oral opioid medications were grouped for analysis, as 93% of patients in the DB cohort and 92% of patients in the SB cohort used Percocet as their primary pain relief medication. Comparing opioid use over the study period between the SB and DB procedures, significantly more opioids were consumed by the DB cohort from the day of surgery until postoperative day 14 (p = 0.011; Table 2). The average number of pills consumed each day over the study period was lower in the SB than the DB cohort (2.8 ± 2.1 v. 3.5 ± 2.5; Table 2).

Maximum NSAID consumption occurred on postoperative day 1 for both procedures. There was no difference in NSAID consumption between the cohorts for the study period (Table 2). In contrast, acetaminophen consumption was significantly higher in the DB cohort than the SB cohort

Table 2. Paired *t* test analyzing medication use on postoperative days 0–14 for oral opioid, oral anti-inflammatory and acetaminophen for single-bundle and double-bundle operations

	Group; mean ± SD			
Medication	Single-bundle	Double-bundle	Mean difference† (95% CI)	*p* value
Oral opioids*	2.8 ± 2.0	3.5 ± 2.5	–0.66 (–1.14 to –0.18)	0.011
Oral NSAID	1.5 ± 0.5	1.6 ± 0.6	–0.09 (–0.22 to 0.03)	0.14
Acetaminophen	0.3 ± 0.1	0.8 ± 0.5	–0.47 (–0.69 to –0.24)	< 0.001

CI = confidence interval; NSAID = nonsteroidal anti-inflammatory; SD = standard deviation.
*Opioid pills included Percocet (oxycodone 5 mg + acetaminophen 325 mg), Tramacet (tramadol 37.5 mg + acetaminophen 325 mg) and Tylenol No. 3 (codeine phosphate 30 mg + caffeine 15 mg + acetaminophen 300 mg).
†Single-bundle minus double-bundle.

Table 3. Single-bundle spinal versus general anesthesia self-reported mean VAS pain scores*

	Group; mean ± SD VAS score*			
Postoperative time	Spinal anesthesia, *n* = 40	General anesthesia, *n* = 39	Mean difference† (95% CI)	*p* value
1 h	0.7 ± 1.5	3.3 ± 1.9	–2.6 (–3.4 to –1.8)	< 0.001
Day 0, pm	34.7 ± 22.3	25.3 ± 21.3	9.4 (–0.37 to 19.2)	0.06
Day 1, am	37.6 ± 28.3	25.1 ± 20.1	12.5 (1.5 to 23.5)	0.027
Day 1, pm	46.1 ± 24.5	41.6 ± 22.0	4.5 (–5.9 to 14.9)	0.39
Day 2, am	37.8 ± 22.2	38.0 ± 26.8	–0.2 (–11.2 to 10.8)	0.97
Day 2, pm	33.0 ± 19.2	34.3 ± 25.0	–1.3 (–11.3 to 8.70	0.80
Day 7	27.8 ± 20.9	30.5 ± 20.8	–2.07 (–12.0 to 6.6)	0.57
Day 14	12.7 ± 14.5	15.4 ± 17.0	–2.7 (–9.8 to 4.4)	0.45

CI = confidence interval; SD = standard deviation; VAS = visual analogue scale.
*No pain = 0; worst pain possible = 100.
†Spinal minus general anesthesia.

Table 4. Double-bundle spinal versus general anesthesia self-reported mean VAS pain scores

	Group; mean ± SD VAS score*			
Postoperative time	Spinal anesthesia, *n* = 21	General anesthesia, *n* = 20	Mean difference† (95% CI)	*p* value
1 h	20.3 ± 23.1	52.0 ± 24.2	–31.7 (–46.6 to –16.7)	< 0.001
Day 0, pm	27.7 ± 21.0	35.5 ± 20.2	–7.9 (–20.9 to 5.2)	0.23
Day 1, am	28.4 ± 19.9	41.1 ± 20.2	–12.7 (–25.4 to –0.03)	0.05
Day 1, pm	46.8 ± 23.2	48.0 ± 19.9	–1.2 (–14.9 to 12.5)	0.86
Day 2, am	30.8 ± 24.0	56.3 ± 20.2	–25.5 (–39.5 to –11.5)	< 0.001
Day 2, pm	25.9 ± 18.4	40.2 ± 18.7	–14.3 (–26.0 to –2.6)	0.018
Day 7	19.1 ± 16.4	31.8 ± 21.7	–12.7 (–24.8 to –0.59)	0.040
Day 14	7.2 ± 5.1	18.1 ± 14.1	–10.9 (–17.5 to –4.3)	0.002

CI = confidence interval; SD = standard deviation; VAS = visual analogue scale.
*No pain = 0; worst pain possible = 100.
†Spinal minus general anesthesia.

(mean of 0.77 ± 0.49 v. 0.3 ± 0.13, $p = 0.001$; Table 2). Maximum consumption of acetaminophen occurred on postoperative day 8 for the DB cohort (mean 1.41 ± 2.2 pills) and on postoperative day 6 for the SB cohort (mean 0.52 ± 2.0 pills).

Spinal anesthesia versus general anesthesia VAS pain scores

In the SB cohort, 40 patients underwent spinal anesthesia and 39 patients underwent general anesthesia (Table 3). Nine patients were converted from spinal anesthesia to general anesthesia; their pain scores were not included in this analysis. In the DB cohort, 21 patients underwent spinal anesthesia and 20 patients underwent general anesthesia (Table 4). Comparing spinal anesthesia with general anesthesia in both the SB and DB cohorts, there was a significant difference in VAS pain scores at 1-hour postsurgery, with patients who received spinal anesthesia reporting significantly lower scores (Tables 3 and 4).

In the SB cohort, patients who received spinal anesthesia reported significantly more pain on postoperative day 1 (8 am) than those who had general anesthesia ($p = 0.027$; Table 3, Fig. 2). For postoperative days 3–14, the SB spinal anesthesia group had a lower mean VAS pain score than the SB general anesthesia group. In the DB cohort, 6 of the 8 assessed time periods demonstrated significantly lower VAS pain scores for spinal than general anesthesia (Table 4). On postoperative day 14, the DB spinal anesthesia group had a significantly lower mean VAS pain score than the DB general anesthesia group (7.2 ± 5.1 v. 18.1 ± 14.1, $p < 0.001$). As illustrated in Figure 3, the mean pain scores of patients in the DB cohort who underwent spinal anesthesia compared with general anesthesia were lower over the entire study period.

Spinal anesthesia versus general anesthesia opioid use

In the DB cohort, opioid use was significantly higher in patients who underwent general anesthesia than spinal anesthesia over the study period (mean 3.9 ± 2.5 pills v. 3.1 ± 2.5 pills, $p < 0.001$; Table 5).

Discussion

This quality assurance study assessing pain scores and medication use was undertaken to identify if there was increased morbidity with respect to pain after DB compared with SB ACLR. Achieving optimal pain management of acute postoperative ACLR is important because pain has been shown to be related to clinical outcomes.[4] We analyzed and compared pain, medication use and type of anesthesia in these 2 independent cohorts. Patients in the DB cohort had increased pain in the first 2 weeks following ACLR, as evidenced by the significant difference in consumption of opioids and acetaminophen. Patients who received spinal anesthesia experienced less pain in the acute postoperative period than those who received general anesthesia.

For patients in both the SB and DB ACLR cohorts, pain and opioid use peaked in the evening of postoperative day 1 and then steadily decreased through postoperative day 14. Previous studies that analyzed pain and analgesia use associated with the SB ACLR procedure reported that both pain and narcotic use peaked on postoperative day 1, followed by a similar decline.[5,8] Direct comparisons could not be made with our results, as previous authors used a different pain measurement scale; however, we observed similar trends.

Patients in the DB cohort followed similar pain score patterns, but demonstrated a trend toward higher mean pain scores across the postoperative period. The DB cohort consumed significantly more opioids and acetaminophen during the study. In the first 48 hours after surgery, patients appeared to self-medicate to a pain level

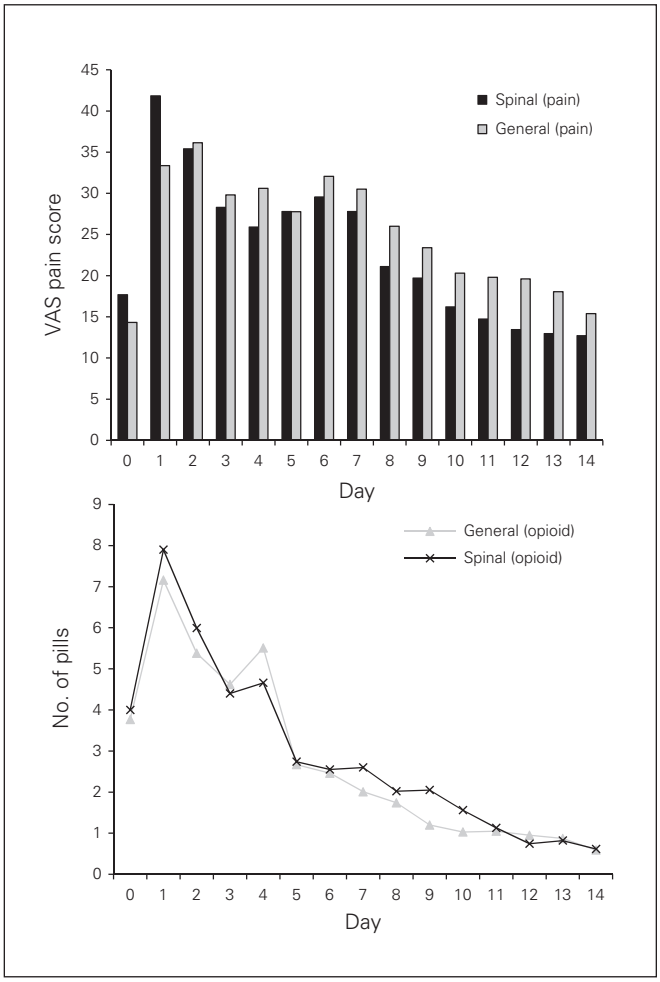

Fig. 2. Single-bundle spinal anesthesia and general anesthesia visual analogue scale (VAS) pain scores and mean opioid use over the 15-day period.

of approximately 30 out of 100. We observed this trend in both patient cohorts; however, patients in the DB cohort required more opioid medication to achieve this pain score. Consumption of NSAIDs was similar between the cohorts throughout the study, possibly because patients were prescribed 1 week of NSAID medication and were following instructions rather than medicating for pain.

Despite the previous lack of data assessing pain scores for the DB ACLR procedure, the significantly greater postoperative opioid use in the DB cohort discovered in this study is not surprising. The DB procedure requires the drilling of an additional tunnel on both the femur and tibia.[7,9] The tibial tunnel for the posterolateral bundle is farther posterior and requires more dissection of the anteromedial tibia. This tunnel also goes through thicker cortical bone, which may cause more thermal damage due to drilling and may be a source of greater pain. Another factor that is quite often overlooked in terms of pain levels is the psychological aspect of surgery, including the patient's expectations regarding postsurgical pain. On this basis, patients who underwent a DB procedure may have interpreted this as undergoing more extensive surgery.

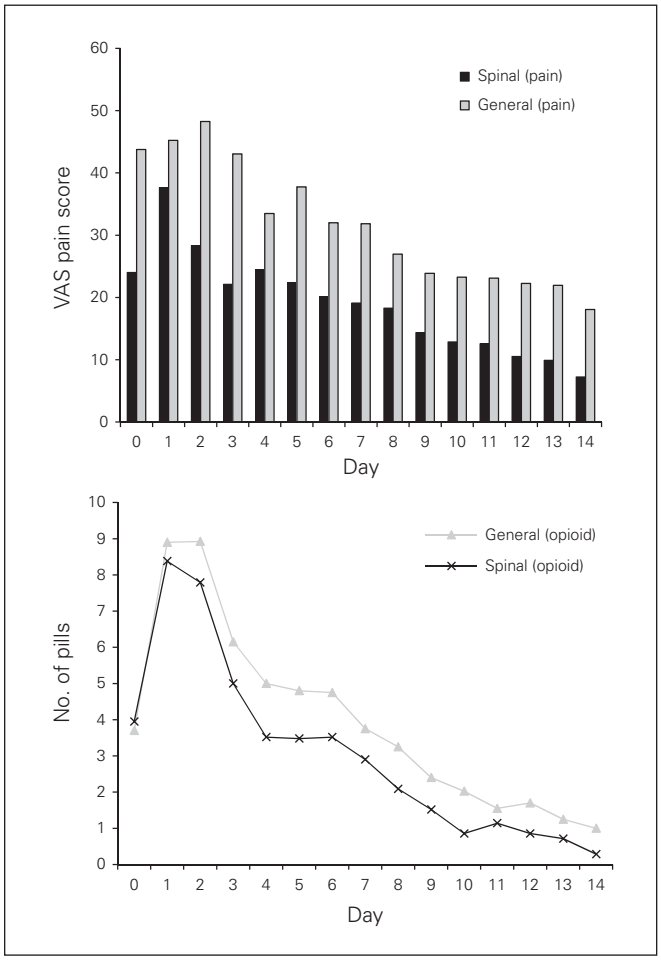

Fig. 3. Double-bundle spinal anesthesia versus general anesthesia visual analogue scale (VAS) pain scores and mean opioid use over the 15-day period.

The only significant difference in VAS pain scores between the SB and DB cohorts occurred at 1 hour postsurgery. If there had been uneven numbers of patients in the spinal anesthesia compared with general anesthesia groups within each cohort, it could have influenced the results because spinal anesthesia provides postoperative analgesia whereas general anesthesia does not.[10] However, the spinal and general anesthesia approaches were equally distributed in both our cohorts; therefore, the method of anesthesia does not explain the difference in VAS pain scores that we observed at this time point. In addition, patients in the DB cohort who received spinal anesthesia recorded significantly greater pain scores 1 hour postoperative than patients in the SB cohort who received spinal anesthesia. This discrepancy is likely related to the duration of the procedures. The DB procedure was significantly longer than the SB procedure, leading to medications administered during surgery being less effective in the DB group by 1 hour postsurgery, thereby resulting in significantly higher pain scores.

For both the SB and DB procedures, the general trend was that patients who received spinal anesthesia experienced less pain over the study period than patients who received general anesthesia. This difference in pain was far more significant in the DB cohort. This trend is consistent with previous studies that demonstrated spinal anesthesia provided longer-term pain relief than general anesthesia for common orthopedic procedures.[10,11] It has been suggested that this phenomenon can be explained by the pre-emptive analgesic effect of the spinal anesthetic.[10,12]

Table 5. Paired *t* test analyzing medication from postoperative days 0–14 for oral opioids,* comparing spinal and general anesthesia for single-bundle and double-bundle operations

	Group; mean ± SD			
Operation	Spinal anesthesia	General anesthesia	Mean difference (95% CI)†	*p* value
Double-bundle	3.1 ± 2.5	3.9 ± 2.5	0.88 (0.62 to 1.12)	< 0.001
Single-bundle	2.9 ± 2.1	2.7 ± 2.1	–0.18 (–0.43 to 0.06)	0.13

CI = confidence interval; SD = standard deviation.
*Opioid pills included Percocet (oxycodone 5 mg + acetaminophen 325 mg), Tramacet (tramadol 37.5 mg + acetaminophen 325 mg) and Tylenol No. 3 (codeine phosphate 30 mg + caffeine 15 mg + acetaminophen 300 mg).
†Spinal minus general anesthesia.

Limitations

There are several limitations to this study. We analyzed 2 independent cohorts, and no randomization was performed. Selection bias did exist, as the patients in the DB cohort were selected for surgery for a variety of reasons, including degree of pivotal laxity, athletic endeavours and patient size. In addition, there was no randomization of the anesthesia procedure. With any pain study, the manifestation as well as the interpretation of pain scores is subjective and highly variable among patients. In addition, the correlation of statistically significant differences in the VAS pain scores to clinically important differences has yet to be determined.

Despite these limitations postoperative pain plays such an important role in each patient's recovery and well-being that any potential for improved postoperative pain management merits investigation. Also, the pain scale used in our study, the VAS, is one of the oldest, easiest and best validated measures to assess pain.[13] The results of our study provide useful clinical information about the differences in pain scores and medication use between SB and DB ACLR.

Conclusion

This quality assurance study demonstrated that adequate pain relief was provided to all ACLR patients in the initial postoperative period. Patients in the DB cohort had increased pain postoperatively, as evidenced by the significant difference in consumption of opioids and acetaminophen. Patients who received spinal anesthesia experienced less pain over the initial 14-day postoperative period than patients who received general anesthesia. This perioperative morbidity should be considered when deciding on the risks and benefits of ACLR surgical procedures. These findings may be clinically important, as higher postoperative pain scores have been linked to lower functional outcomes and quality of life scores. Further investigation of the effect of acute postoperative pain on functional outcome is warranted for both the SB and DB ACLR procedures.

Competing interests: None declared.

Contributors: All authors designed the study and acquired the data, which S.A. Macdonald, L.A. Hiemstra, G.M.L. Buchko and S. Kerslake analyzed. S.A. Macdonald wrote the article, which all authors reviewed and approved for publication.

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