Reports of Original Investigations

Evolution of ultrasound guided axillary brachial plexus blockade: retrospective analysis of 662 blocks

[Évolution du bloc du plexus brachial par approche axillaire sous échoguidage : une analyse rétrospective de 662 blocs]

Nick Lo MD,* Richard Brull MD FRCPC,* Anahi Perlas MD FRCPC,* Vincent W.S. Chan MD FRCPC,* Colin J.L. McCartney MBChB FRCA FCARCSI FRCPC,† Raffaele Sacco,* Hossam El-Beheiry MBBCh PhD FRCPC*

Purpose: Ultrasound (US) is being used increasingly to guide needle placement during axillary brachial plexus blockade (AXB). This retrospective study investigated whether US guidance can increase the success rate, decrease block onset time, and reduce local anesthetic (LA) volume for AXB compared to a traditional (TRAD) approach, namely, peripheral nerve stimulation (PNS) and transarterial (TA) techniques.

Methods: The anesthetic records, operative reports, discharge summaries, and surgical consultation notes of all patients who had undergone AXB for surgical anesthesia at the Toronto Western Hospital, between October 2003 and November 2006 were, retrospectively reviewed for evidence of block success and associated complications. Block success was defined as the achievement of surgical anesthesia without additional LA supplementation.

Results: Among the 662 patients, 535 patients underwent AXB using US guidance (US group), and 127 using TRAD techniques (TRAD group), namely, 56 using PNS (PNS subgroup) and 71 using the TA technique (TA subgroup). The block success rate was higher in the US group compared to the TRAD group (91.6% *vs* 81.9%, $P = 0.003$). The LA volume used for AXB was less in the US group compared to the TRAD group (39.8 ± 6.4 mL *vs* 46.7 ± 17.1 mL, $P < 0.0001$). Ultrasound group patients spent less time in the block procedure room than those in the TRAD group (30.6 ± 14.2 min *vs* 40.1 ± 27.3 min, $P < 0.0001$). When analyzed by subgroup, the US group demonstrated significantly greater success and shorter duration in the block room compared to the PNS subgroup, but not the TA subgroup. Complications (inadvertent intravenous LA injection, and transient neuropathy) were lower in the US group compared to the TRAD group (0.37% *vs* 3.15%, $P = 0.014$).

Conclusions: Our results suggest that US-guided AXB may improve block success, reduce the local anesthetic volume used, and shorten the time spent in the block room compared to traditional nerve localization techniques.

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***Objectif** : L'ultrason (US ou échoguidage) est de plus en plus utilisé pour guider le positionnement de l'aiguille pendant le bloc du plexus brachial par approche axillaire (AXB). Cette étude rétrospective a cherché à déterminer si l'échoguidage peut améliorer le taux de réussite, raccourcir le délai d'installation et réduire le volume d'anesthésique local (AL) pour l'AXB par rapport à une approche traditionnelle (TRAD), c'est-à-dire aux techniques de stimulation des nerfs périphériques (PNS) et par transfixion artérielle (TA).*

From the Department of Anesthesia and Pain Medicine,* Toronto Western Hospital, University Health Network; and the Department of Anesthesia,† Sunnybrook Health Sciences Center, Toronto, Ontario, Canada.

Address correspondence to: Dr. Richard Brull, Department of Anesthesia and Pain Medicine, Toronto Western Hospital, University Health Network, 399 Bathurst St., Toronto, Ontario M5T 2S8, Canada; Fax: 416 603-6494; E-mail: richard.brull@uhn.on.ca

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Méthode *: Les dossiers anesthésiques, les dossiers d'opération, les résumés de congés et les notes de consultation chirurgicale de tous les patients subissant un AXB dans le cadre d'une anesthésie chirurgicale au Toronto Western Hospital entre octobre 2003 et novembre 2006 ont été évalués rétrospectivement afin de trouver des données probantes quant à la réussite du bloc et aux complications associées. La réussite d'un bloc était définie comme l'obtention d'une anesthésie chirurgicale sans addition supplémentaire d'AL.*

Résultats *: Parmi les 662 patients dont les dossiers ont été évalués, 535 patients ont subi un AXB échoguidé (groupe US), et 127 à l'aide de techniques traditionnelles (groupe TRAD), dont 56 patients à l'aide de PNS (sous-groupe PNS) et 71 à l'aide de la technique TA (sous-groupe TA). Le taux de réussite du bloc était plus élevé dans le groupe US comparé au groupe TRAD (91,6 % vs 81,9 %, P = 0,003). Le volume AL utilisé pour l'AXB était moins élevé dans le groupe US par rapport au groupe TRAD (39,8 ± 6,4 mL vs 46,7 ± 17,1 mL, P < 0,0001). Les patients du groupe échoguidé ont passé moins de temps en salle d'anesthésie régionale que ceux du groupe TRAD (30,6 ± 14,2 min vs 40,1 ± 27,3 min, P < 0,0001). Lorsque les résultats ont été analysés par sous-groupe, le groupe US a montré un taux de réussite significativement plus élevé et un séjour plus court en salle d'anesthésie régionale par rapport au groupe PNS, mais non par rapport au groupe TA. Les complications (injection intraveineuse involontaire d'AL et neuropathie temporaire) étaient moins courantes dans le groupe US que dans le groupe TRAD (0,37 % vs 3,15 %, P = 0,014).*

Conclusions *: Nos résultats suggèrent qu'un bloc du plexus brachial par approche axillaire échoguidée pourrait améliorer le taux de réussite du bloc, réduire le volume d'anesthésique local utilisé, et réduire le temps passé en salle d'anesthésie régionale par rapport aux techniques traditionnelles de localisation des nerfs.*

THE axillary approach to brachial plexus blockade (AXB) can provide superior pain relief, reduce nausea and vomiting, and expedite hospital discharge compared to general anesthesia for hand surgery.[1] Given its record of success and safety, as well as the ease with which the technique is learned and performed, AXB is the most commonly performed peripheral nerve block by members of the Society for Ambulatory Anesthesia.[2] The traditional (TRAD) approach used to localize the brachial plexus includes the use of surface anatomic landmarks, seeking paresthesias, and the elicitation of motor responses by electrical nerve stimulation. These TRAD techniques can result in inconsistent success rates,[3] the need for a "rescue block,"[4] or an unplanned general anesthetic,[3] all with increased costs and time requirements.[4] Further, blind techniques for AXB may increase the potential for complications, including nerve injury and vascular puncture.[5]

Real time ultrasonographic (US) guidance has recently gained tremendous popularity for nerve localization. Despite the recent upsurge in interest, a critical review of the literature reveals that the evidence in favour of improved success with US, compared to traditional nerve localization techniques, is wanting.[3,4,6–8] Existing randomized controlled trials support that US can hasten AXB performance and onset times as well as improve block 'quality' and duration,[3,4,6,8,9] but the ultimate question of improved block success (albeit the definition of 'success' can be highly variable) remains unresolved. Chan *et al.*[10] as well as Liu *et al.*[8] both demonstrated improved success rates using US compared to peripheral nerve stimulation (PNS) for AXB. In contrast, Casati *et al.*[9] found no difference between the two guidance modalities. Large-scale outcome data to establish whether or not US guidance can improve the success rate of peripheral nerve blockade, in general, and AXB in particular, are currently lacking.[4] The objective of the present study was to retrospectively examine the success rates of US guidance, compared to traditional nerve localization techniques, for AXB at our home institution. We hypothesized that US guidance can improve the success compared to traditional techniques.

Methods

After obtaining Institutional Ethics Review Board approval, medical records of all patients who had undergone AXB for surgical anesthesia at the Toronto Western Hospital for hand, wrist, or elbow surgery, between October 2003 and November 2006, were reviewed. The AXBs were performed either under US-guidance[7] or using TRAD, specifically, multiple injection PNS[11] or the transarterial (TA)[12] technique. Peripheral nerve stimulation-guided AXB was performed using a nerve stimulator (Stimuplex®, B. Braun Medical, Bethlehem, PA, USA) with a stimulating frequency of 2 Hz, and a pulse width of 100 μsec. A distal motor response in the hand was sought in the distribution of each of the median, ulnar, and radial nerves, with a current threshold of 0.5 mA or less. Transarterial-guided AXB was performed using a 23G hypodermic needle (BD Medical, Franklin Lakes, NJ, USA) and 1.5% lidocaine 10 mg kg^{-1}, with 1:200,000 epinepherine. Ultrasound guidance became the nerve localization method of choice for AXB at our institution in mid-2004. At the Toronto Western Hospital, US-guided AXB is routinely performed using a 22G insulated needle (Stimuplex, B. Braun Medical, Bethlehem, PA, USA) and nerve stimulator as adjunctive

Table I Patient characteristics

	US group (n = 535)	TRAD group (n = 127)	P-Value	PNS subgroup (n = 56)	P-Value	TA subgroup (n = 71)	P-Value
Male / Female (n)	297 / 238	73 / 54	0.762	34/22	0.546	39/32	0.972
Age (yr)	47.4 ± 14.9	44.6 ± 14.8	0.057	45.2 ± 14.8	0.293	44.2 ± 14.9	0.090
BMI (n)							
Less than 25	176	41		19		22	
25 - 30	182	40		20		20	
30.1 – 40	124	32		14		18	
> 40	21	1		0		1	
Unknown	32	13		3		10	
			0.413		0.564		0.104
Surgical site (n)							
Hand	384	104		50		54	
Wrist	123	20		5		15	
Elbow	26	1		0		1	
Forearm	2	2		1		1	
			0.039		0.016*		0.442

*Significant difference ($P < 0.017$) compared to US group. n = number of patients; BMI = body mass index; PNS = peripheral nerve stimulation technique; TA = transarterial technique; TRAD = traditional blind nerve localization technique; US = ultrasound-guided technique.

confirmation of nerve identity, but not necessarily needle-nerve proximity. Local anesthetic (LA) was injected to produce a circumferential spread around the median, ulnar, and radial nerves. A 50:50 mixture of 2% lidocaine and 0.5% bupivicaine with 1:200,000 epinephrine is the most commonly used LA for PNS- and US-guided AXB. The volume of LA used most often for either PNS- or US-guided AXB was 40 mL.

For each patient, the Toronto Western Hospital regional anesthesia electronic database (created in October 2003), intraoperative anesthetic record, postoperative anesthetic record, and surgeon's preoperative consultation, intraoperative report, and follow-up clinic notes were reviewed, in order to determine block success and to identify any associated major complications (e.g., unintentional intravascular injection and persistent neurological deficit). Axillary brachial plexus blockade success was graded as *complete* (no LA supplementation or 'rescue block' required for surgical anesthesia), *incomplete* (LA supplementation or 'rescue block' required), or *failed* (general anesthesia required).

According to our routine clinical practice, all patients who receive regional anesthesia for surgery received midazolam and/or low-dose propofol infusion, intraoperatively, as needed for anxiolysis. Each AXB was performed by one of 11 attending staff regional anesthesiologists, or one of 43 regional anesthesia trainees (fellows or residents) under direct staff supervision in our block room.

All AXBs were administered in our "block room" – a monitored setting where patients receive regional anesthesia prior to entering the main operating room for their surgical procedures. The duration of the time spent in the block room was defined as the number of minutes elapsed from initial arrival of the patient into the room, to completion of the block. This time period not only encompassed block performance time, but also included patient preparation time and block assessment time. The duration of time spent in Phase I recovery (high acuity monitoring) and Phase II recovery (lower acuity monitoring), was defined as the number of minutes for which the patient was present in each of these locations.

Statistical analysis

Data were analyzed by using MedCalc for Windows, version 9.3.7.0 (MedCalc Software, Mariakerke, Belgium). Differences in proportions were compared using the Chi-squared test for trend. Comparison of means was analyzed using the t test. The software implemented algorithms to correct for heterogeneity of variances between every two groups when necessary. Significance was assumed at $P < 0.017$, using the Bonferroni correction for multiple comparisons. In this study, the Bonferroni correction was used to determine the P-value for multiple comparisons of different endpoints and outcomes between the different groups (i.e., US, TA and PNS groups). We limited the utilization of such mathematical corrections of the

TABLE II Outcome measures following ultrasound-guided axillary brachial plexus block compared to traditional nerve localization techniques

	US group (n = 535)	TRAD group (n = 127)	*P*-Value	PNS subgroup (n = 56)	*P*-Value	TA subgroup (n = 71)	*P*-Value
Success (n)							
Complete	490 (91.6%)	104 (81.9%)		44 (78.6%)		60 (84.5%)	
Difference (95% CI)		9.7% (3.4-17.6%)		13.0% (3.9-25.6)		7.1% (0.0-17.5)	
Incomplete	27 (5.0%)	14 (11.0%)		7 (12.5%)		7 (9.9%)	
Difference (95% CI)		-6.0% (1.1-12.8)		-7.5% (0.8-18.7)		-4.9% (-0.6-14.2)	
Failed	18 (3.4%)	9 (7.1%)		5 (8.9%)		4 (5.6%)	
Difference (95% CI)		-3.7% (-0.1-9.7)		-5.5% (0.1-15.9)		-2.2% (-1.7-10.3)	
			0.003*		0.003*		0.085
Local anesthetic volume (mL)	39.8 ± 6.4	46.7 ± 17.1	< 0.0001*	44.2 ± 16.8	0.0001*	56.9 ± 15.4	< 0.0001*
Duration in block room (min)	30.6 ± 14.2	40.1 ± 27.3	< 0.0001*	46.4 ± 31.7	< 0.0001*	35.0 ± 22.1	0.023
Duration of surgery (min)	68.2 ± 32.5	67.0 ± 31.1	0.706	66.8 ± 32.7	0.759	67.2 ± 29.7	0.806
Phase I recovery (min)	49.9 ± 33.1	51.3 ± 26.8	0.658	44.6 ± 28.2	0.249	56.7 ± 24.6	0.095
Phase II recovery (min)	65.8 ± 37.9	72.1 ± 71.3	0.167	78.7 ± 97.2	0.050	65.9 ± 31.0	0.983
Major complications	2	4	0.014*	2	0.055	2	0.108

*Significant difference ($P < 0.017$) compared to US group. *Difference* is calculated as follows: % success in US group minus % success in other group. n = number of patients; CI = confidence interval; PNS = peripheral nerve stimulation technique; TA = transarterial technique; TRAD = traditional blind nerve localization technique; US = ultrasound-guided technique.

P-value to situations where the same test was repeated in many sub samples, such as when the groups were stratified according to age, gender, technique applied, success rates, etc. Data are presented as numerical count (n) or as mean ± SD.

Because of the retrospective design of the study, there was no *a priori* sample size calculation (i.e., all patients in the data base satisfying the inclusion criteria were included in the analysis). However, retrospective statistical power analysis was performed using the software, G*Power V3.0.8 (Franz Faul, Kiel University, Germany). Statistical power for the tests performed pertaining to the different outcomes that showed significant *P*-values all had powers of > 0.80.

Results

Seven hundred and eighty-five patients underwent AXB for surgical anesthesia during the specified time period. One hundred and twenty-three patients were excluded from the analysis because the nerve localization technique could not be determined. Of the remaining patients (n = 662), 535 underwent AXB using US guidance (US group), and 127 using TRAD techniques (TRAD group), specifically, 56 using PNS (PNS subgroup) and 71 using the TA technique (TA subgroup). The groups were similar in regards to preoperative patient characteristics (Table I). Ultrasound-guidance resulted in more *complete* blocks (91.6% *vs* 81.9%, $P = 0.003$), with a shorter duration of time spent in the block room (30.6 ± 14.2 min *vs* 40.1 ± 27.3 min, $P < 0.0001$) compared to the TRAD group. The volume of LA used in the US group (39.8 ± 6.4 mL) was less compared to the TRAD group (46.7 ± 17.1 mL, $P < 0.0001$). The mean duration of surgery, and the mean duration of time spent in either Phase I or II recovery, did not differ between US and TRAD groups.

When subgroup analysis was applied to the TRAD group, there was no difference in any outcome measure between the PNS and TA subgroups, with the exception of volume of LA used (44.2 ± 16.8 mL PNS *vs* 56.9 ± 15.4 mL TA, $P < 0.0001$). Ultrasound-guidance provided significantly more *complete* blocks (91.6% *vs* 78.6%, $P = 0.003$) with a shorter duration of time spent in the block room (30.6 ± 14.2 min *vs* 46.4 ± 31.7 min, $P < 0.0001$) compared to the PNS subgroup, but not when compared to the TA subgroup. The volume of LA used in the US group (39.8 ± 6.4 mL) was less, compared to both the PNS (44.2 ± 16.8 mL, $P = 0.0001$), and TA (56.9 ± 15.4 mL, $P < 0.0001$) subgroups (Table II).

The primary block provider was indicated in 559 of 662 cases. There was no significant difference in the percentage of *complete*, *incomplete* and *failed* blocks in the US or TRAD groups, when comparing staff anesthesiologists to trainees (Table III).

TABLE III Success rates according to provider for ultrasound-guided axillary brachial plexus block compared to traditional nerve localization techniques*

	US-guided technique			TRAD-guided technique		
	Staff performed (n = 84)	Trainee performed (n = 374)	P-Value	Staff performed (n = 13)	Trainee performed (n = 88)	P-Value
Success (n)						
Complete	78 (92.9%)	341 (91.2%)	0.778	12 (92.3%)	73 (83.0%)	0.659
Incomplete	3 (3.6%)	21 (5.6%)	0.625	1 (7.7%)	9 (10.2%)	0.824
Failed	3 (3.6%)	12 (3.2%)	0.864	0 (0.0%)	6 (6.8%)	0.745

*Block provider data was specified in 559 of 662 blocks. n = number of axillary brachial plexus blocks performed; TRAD = traditional blind nerve localization; US = ultrasound.

There were six cases of major complications associated with AXB. Five of these events involved intravascular LA injections during AXB: two were in the US group (frequency: 2/535, or 0.37%), two were in the TA subgroup (frequency: 2/71, or 2.82%), and occurred in the PNS subgroup (frequency: 1/56, or 1.79%). Of the two patients in the TA subgroup, one experienced a generalized seizure due to intravascular LA injection. This patient demonstrated no signs or symptoms of impending systemic LA toxicity prior to the sudden onset of generalized convulsions. The seizure was treated immediately with midazolam 2 mg *iv* followed by propofol 200 mg *iv* bolus. The patient's hand surgery was cancelled, and following a period of same-day observation, the patient was discharged home without adverse sequelae. One patient in the PNS subgroup suffered postoperative AXB-associated neuropathy, which resolved spontaneously after approximately two months. The complication rate was significantly lower in the US group compared to the TRAD group (0.37% *vs* 3.15%, P = 0.014) (Table II).

Discussion

The benefits of peripheral nerve blockade for surgical anesthesia have long been undermined by its inconsistent success rates, variable block performance and onset times, as well as complications, all of which may well be related to the blind nature of traditional nerve localization techniques. Within the present study conditions, our retrospective data suggest that US guidance increases the success rate of AXB compared to traditional nerve localization techniques, despite smaller LA volumes used for US-guided AXB. Our retrospective results are similar to the findings from randomized controlled trials recently published by our group[4] and by Liu *et al.*,[8] both of which demonstrated a significant improvement in success rates with US-guidance compared to PNS for AXB. In contrast, Casati *et al.*[9] demonstrated no difference in success rates between US and PNS techniques when AXB is performed by expert regional anesthesiologists.

The majority of peripheral nerve blocks performed at our academic institution are performed by trainees, under the direct supervision of staff anesthesiologists, rather than by the staff anesthesiologists themselves. The present study demonstrated no significant difference between the success rates of AXBs performed by staff compared to trainees in the US or TRAD groups; therefore, the difference between our findings and those of Casati *et al.* cannot be fully explained by differences in the providers' level of training alone.

Further, in contrast to Sites *et al.*,[3] we were unable to demonstrate a difference in success rates in subgroup analysis when comparing US-guided AXB to the TA technique. We did, however, find that significantly more LA volume was used for the TA technique compared to US-guided AXB, which may at least partially explain the equivalent success rates. Had the volumes of LA been fixed across all subgroups, it is plausible that we may have found a statistical difference in success rates between the US and TA groups.

Unlike our previously published randomized trial of US compared to PNS for AXB,[4] the present study suggests that US may contribute to a reduction in the incidence of major complications compared to traditional techniques. Indeed, the strength of our retrospective review is its relatively large sample of US-guided AXBs. However, given the infrequency of such occurrences in modern anesthetic practice, considerably larger sample sizes would nonetheless be necessary to either confirm or refute this trend.

Finally, our study found that patients undergoing US-guided AXBs spent significantly less time in the block room, compared to those who underwent TRAD AXBs, which may be attributable to faster block onset and/or relative ease of block performance with US. A shorter duration of time spent in the block room may contribute to a reduction in perioperative costs.[10,13]

Our single-centre, retrospective study has several limitations. Because of the limited data available, we were unable to report on either block onset or block duration. Our retrospective review is also subject to incomplete charting; especially vulnerable is the frequency of complications, which could be underestimated due to potential lack of documentation.[14,15] Further, as our practice patterns for hand surgery evolved from primarily TA AXB prior to 2003, to multiple endpoint PNS in 2004, and then to US-guided AXB in mid-2004 (and finally to US-guided supraclavicular block in mid-2005), so too, did our primary choice of LA. While the LA type may have affected pharmacokinetic parameters such as block onset and duration, we do not believe that the differences in LA type substantially affected the pharmacodynamic parameters such as success and major complications, which were investigated in this study. Moreover, our unique data includes and reflects our early developmental stages (self-teaching and mutual learning) and preliminary experience with US-guided AXB, and yet still suggests superior success with US-guidance compared to traditional techniques. Lastly, it is unclear what role, if any, adjunctive nerve stimulation, which is routinely used in conjunction with US for AXB at our institution, played in improving the success rate of the US group compared to the TRAD group. Our recent prospective trial comparing US to PNS for AXB suggests that adjunctive nerve stimulation provides does not increase success rates.[4]

In conclusion, this retrospective review suggests that US-guided AXB may improve block success, reduce the volume of LA used, and shorten the time spent in the block room, compared to traditional nerve localization techniques. Ultrasound guidance may also reduce the incidence of major AXB complications compared to traditional nerve localization techniques. Future large-scale, multi-institutional, prospective studies are needed, to assess whether or not US can reduce the incidence of major complications compared to traditional techniques.

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