Ultrasound-guided supraclavicular brachial plexus anaesthesia improves arteriovenous fistula flow characteristics in end-stage renal disease patients

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Background: Surgical construction of an arteriovenous fistula is preferred for end-stage renal failure patients requiring long-term haemodialysis.

Methods: Patients were randomised into two groups: brachial plexus group ($n = 30$) or local infiltration group ($n = 30$). In all patients, a radiocephalic arteriovenous fistula was created by an experienced surgeon using a standard surgical technique. In both groups 20 ml of 0.375% ropivacaine was used. Doppler assessment of vessels was performed at fixed time intervals.

Results: Primary patency rate was 100% in the brachial plexus block group whereas there was 10% fistula failure rate in the local infiltration group (p-value = 0.237). Diameter of the vessels, peak systolic velocity, mean diastolic velocity, and blood flow at 30 minutes, 48 hours, 2 weeks, and 6 weeks after the fistula creation was significantly greater than the preoperative diameter in all patients (p-value < 0.05). Intergroup comparison revealed that vascular parameters were significantly better in the brachial plexus analgesia group versus local infiltration group at all observation points up to and including six weeks post fistula creation (p-value < 0.05).

Conclusion: Brachial plexus anaesthesia significantly dilates the vessel diameter and increases blood flow whereas local infiltration has a negligible effect on vessel diameter and blood flow.

Keywords: arteriovenous fistula, end-stage renal disease, ultrasound guided supraclavicular block

Introduction

The prevalence of end-stage renal disease (ESRD) cases is rising worldwide. The three main treatment options for ESRD are haemodialysis, peritoneal dialysis and renal transplantation. In the geriatric population and in patients awaiting renal transplant surgery haemodialysis has traditionally been considered the most viable option.[1] Placement of a radiocephalic arteriovenous fistula (RCAVF) is the procedure of choice for patients with ESRD receiving maintenance haemodialysis because of its reliable patency, low complication rate and preservation of alternate future access sites. However, this procedure is not always easy to perform because of the poor quality of distal cephalic veins, multiple prior venepunctures and cannulations.[2] Approximately 25–30% of initial RCAVF placements are reported to be unsuccessful, leading to inadequacy of blood flow, thrombosis and narrowing of vessels. Maturation of the fistula is affected by patient characteristics and the surgical technique. Larger vein diameter and high blood flow through the fistula are the two important predictors of successful RCAVF function.[1,3]

Anaesthetic modalities used for RCAVF creation such as monitored anaesthesia care, regional blocks and general anaesthesia may affect the characteristics of blood flow across the fistula.[1] RCAVF is the preferred route for haemodialysis but this procedure may not be successful due to intraoperative spasm of the radial artery because of enhanced sympathetic activity.[2,4] Regional anaesthetic techniques have been used to improve the success of vascular access procedures because of sympatholytic effects. The technique produces significant vasodilatation whilst minimally altering the patient's haemodynamic parameters. There is increased blood flow through the fistula and maturation time is reduced.[3] The supraclavicular brachial plexus block has a high success rate due to blockade of the ulnar and musculocutaneous nerves. These nerves can be missed during the interscalene and axillary approach respectively.[5]

Ultrasound guidance (USG) enhances the view of nerve bundles, provides real-time assessment of needle advancement, assists with avoiding key structures (e.g. blood vessels, pleura etc.), and facilitates spread of local anaesthetic along the targeted nerves.[6] The use of this non-invasive technology to view nerve bundles while performing nerve blocks has significantly improved the success rate of the block as well as the safety of the procedure. Moreover, total volume of drug required is also reduced due to precise location and direct visualisation of nerves when using ultrasound.[6]

According to a recent study, authors observed that infraclavicular brachial plexus block provided higher blood flow in the radial artery and arteriovenous fistula (AVF) in a Turkish population as compared with infiltration anaesthesia.[7]

Material and methods

After institutional ethical committee approval and written informed consent, this prospective, single-blind randomised study enrolled 60 consecutive ASA II–III ESRD adults, aged 18–60 years, scheduled for creation of RCAVF to facilitate haemodialysis from 1 July 2011 to 30 June 2012. Exclusion criteria were: local infection, allergy to local anaesthetics, clinically significant coagulopathy, anatomical variation at the intended site of brachial plexus injection, body mass index more than 35, revision of previously blocked AVF and failed surgical procedure.

A detailed history regarding physical health, coexisting medical problems, current medications, allergies, previous anaesthetic and surgical experience were noted before surgery. The upper limb,

shoulder and neck were examined to detect any sign of previous trauma, muscle atrophy, venous hypertension related to proximal vein obstruction or chronic ischaemia. Relevant laboratory investigations were reviewed such as the coagulation profile.

In the operating room, baseline monitoring was established. Patients were randomised into two groups by computer-generated randomisation number using block randomisation design with a block size of six. Group 1 patients received USG supraclavicular brachial plexus block (BPBG) using 20 ml of a 0.375% solution ropivacaine to encircle the neural bundles. For Group 2, the local infiltration group (LIG), the surgical site was infiltrated with 20 ml of 0.375% ropivacaine.

For performing the USG supraclavicular block, a 5–12 MHz sterile compact linear transducer was used. Once the subclavian artery was visualised, the area lateral and superficial to it was explored until the plexus was seen. A caudad–cephalad rocking motion was used to find the plane where the nerves were best visualised, with a characteristic 'honeycomb' appearance (hypoechoic). Adequate skin anaesthesia was obtained by using lignocaine (2%, 2–3 ml) and a 26-G hypodermic needle; a 22-G spinal needle was than inserted in a medial to lateral direction to reach the lateral corner of the subclavian artery (SA) and above the first rib. As the needle was slowly advanced towards the first rib, 0.5–1 ml saline was used to hydro-dissect the facial sheath and perineural tissues. Once the trajectory of the needle was close to the brachial plexus, anaesthetic solution was instilled with intermittent aspiration until the entire plexus was encircled. The adequacy of sensory block was assessed by pin-prick sensation at the surgical site. If the analgesia was not adequate, the fistula was created using local anaesthetic infiltration and the case was excluded from the study.

A standardised surgical technique was used for creation of all AVF, employing a minimal vessel touch surgical dissection technique to explore vessels and limited dissection of the cephalic vein and radial artery. The artery was clamped using a coronary artery clamp, and an end-to-side anastomosis was made.

Blood flow measurement technique
A Doppler probe over the target vessels, i.e. radial artery and draining AVF vein, was used for the acquisition of data relating to blood flow in RCAVF. The integrated software in a vascular ultrasound machine (FIDG HD 11 5–12 MHz) automatically gives various values like peak systolic velocity (PSV), mid-diastolic velocity (MDV), pulsatility index (PI), resistivity index (RI), and blood flow. Vessel diameter was calculated on 2D mode. The blood flow readings were recorded on M-mode once the signal was stabilised

for at least 30 seconds and consistent values were obtained. The measurements for blood flow were done before surgery (baseline), after USG block, 30 minutes after surgery, 3 hours after surgery, 48 hours after surgery, at 2 weeks and at 6 weeks postoperatively. All the sonographic evaluations were performed using a FIDG HD 11 5–12 MHz linear array transducer by an observer who was blinded to the type of anaesthetic technique used, after the patient had rested quietly in the supine position for 5 minutes. Doppler assessment of vessels was done with regard to vessel diameter, peak systolic velocity, mean diastolic velocity, resistivity index (RI), blood flow (ml/min) at various time intervals including baseline, pre-block, 30 minutes after surgery, 48 hours after surgery, 2 weeks and 6 weeks postoperatively. In addition to these parameters, fistula patency was also assessed at these time intervals.

The primary end point of this study was the comparison of blood flow and other fistula maturation factors in the two groups at different time intervals up to the sixth week after surgery. Secondary end points were evaluating the adequacy of ultrasound-guided supraclavicular brachial plexus block and immediate complications related to the block.

Statistical analysis
The statistical analysis was done by using the Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, version 15.0 for Windows). Data were expressed as mean ± S.D or mean (range) as appropriate. Normality of data was checked by measures of Kolmogorov–Smirnov tests of normality. Normally distributed data means were compared by using Student's t-test. For skewed data or for scores a Mann–Whitney test was applied for the two groups. For time-dependent changes a repeated measure ANOVA was applied. A p-value of less than 0.05 was taken to be statistically significant.

Observations and results
The demographic profile and coexisting morbidities of patients were comparable (Table 1). The arterial and venous parameters prior to the fistula creation were also comparable ($p > 0.05$). All patients were evaluated up to six weeks after surgery (consort diagram, see Figure 1). The readings were taken in the arterialised vein and radial artery at 5 cm proximal to the AV fistula. The comparative changes observed in various parameters before anaesthesia and during the follow-up period of the study are summarised in bar diagrams in Figure 2.

Doppler vascular parameters of diameter, PSV, MDV and blood flow at 30 minutes, 48 hours, 2 weeks and 6 weeks after the fistula creation were significantly greater than the preoperative diameter in both groups (p-value < 0.05). Amongst the two groups, vascular parameters of diameter, PSV, MDV and blood flow were significantly

Table 1: Demographic data

Factor		Group 1 (n = 30)	Group 2 (n = 30)	p-value
Mean age	(years)	41.33 ± 12.906	47.47 ± 12.272	0.064
Gender*	(M:F)	25:5	21:9	0.222
Weight	(kg)	51.509 ± 6.5538	53.75 ± 6.669	0.291
Co-morbidities	DM	4	4	1
	HTN	10	11	0.827
	DM, HTN	5	9	0.285
	HTN, HBS+	1	0	1
	IgA nephropathy	9	6	0.439
	IgA nephropathy with HBS+	1	0	1

Notes: IgA = IgA nephropathy disease; HBS+ = hepatitis B surface antigen positive
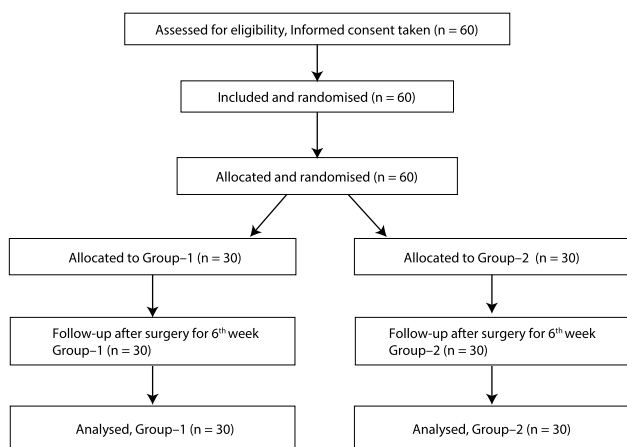
Figure 1: Consort diagram of study.

more in the brachial plexus analgesia group versus local infiltration group at all points of observations after the block until six weeks post fistula creation (*p*-value < 0.05). Resistivity index (RI) values
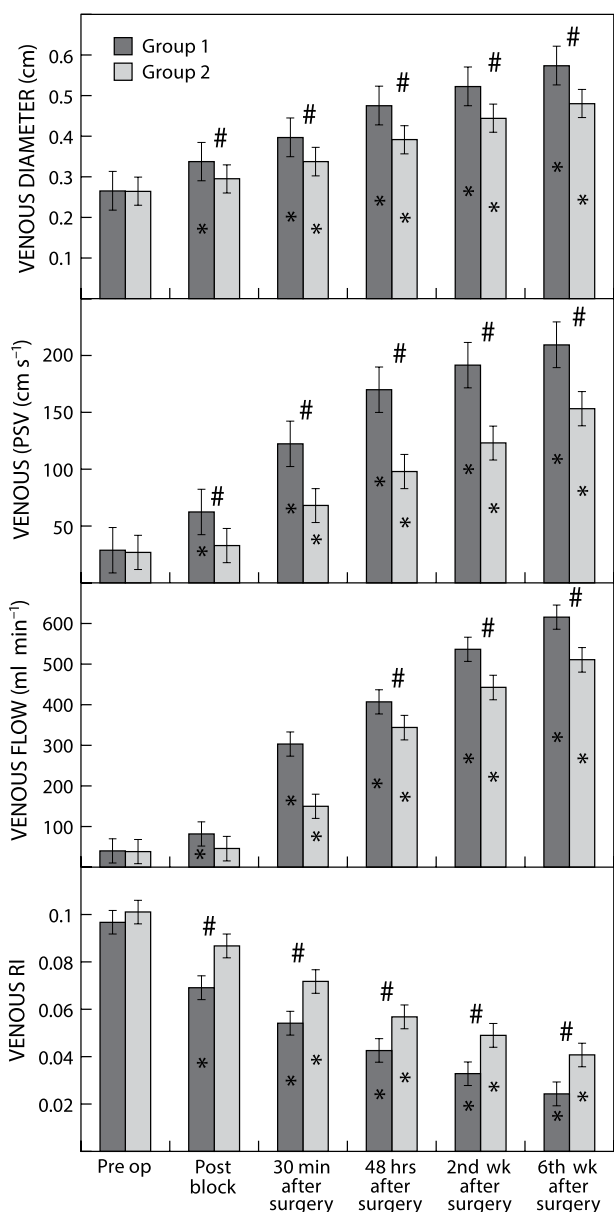

Figure 2: Comparative changes in Doppler vascular (venous) indices at various times.

were low in the brachial plexus block group. Patency rate at six weeks was 100% in the brachial plexus block group, whereas there was a 10% fistula failure rate in the local infiltration group (*p*-value = 0.237).

Discussion

Autogenous RCAVF is the preferred vascular access for long-term hemodialysis.[8] Arterial narrowing and calcification are relatively common in patients with chronic kidney disease, especially in patients with diabetes and hypertension.[9] There are many factors that can affect the outcome of RCAVF, such as old age, female gender, history of smoking, previous venous cannulation and underlying diseases like diabetes, hypertension, peripheral vascular diseases, or coronary artery diseases.[10] The patency of an RCAVF is mostly dependent on blood flow in the radial artery. The most frequent cause of failure of AVF is neointimal hyperplasia, typically occurring in the juxta-anastomotic vein. Hyperplasia develops during the first postoperative month.[10] Results of the present study indicate that USG supraclavicular brachial plexus block provides higher blood flow in the radial artery and AVF in both the early and late postoperative periods as compared with AVF created under local infiltration anaesthesia. Vascular surgical procedures are particularly prone to vessel spasm, possibly because of increased sympathetic tone and local handling of vessels, which can impair blood flow and potentially lead to early thrombosis of the fistula. Anaesthetic techniques used for RCAVF creation like monitored anaesthesia care, regional blocks and general anaesthesia may affect the characteristics of blood flow across the fistula and hence influence fistula failure.[1] Malinzak and colleagues suggested that use of regional blocks may improve the success of vascular access procedures by producing significant vasodilatation, greater fistula blood flow, sympatholytic effects and decreased maturation time while minimally altering blood pressure and heart rate.[11]

A minimum preoperative vessel diameter of 2 mm was first suggested by Silva and colleagues who reported good AVF outcomes (8% early failure, 83% functional primary patency at 1 year).[12] Brimble and colleagues reported that a minimum preoperative venous diameter of 2.5 mm was required for fistula maturation.[13] Silva and colleagues took a minimum of 2.5 mm preoperative cephalic vein diameter as the cut-off for their fistula formation.[12] Malovrh and colleagues reported a similar mean preoperative flow rate of 54.5 ml/min in vessels with a successful outcome and a mean flow rate of 24.1 ml/min in those that failed.[14] Sedlach and colleagues suggested a preoperative threshold PSV of at least 50 cm/sec for fistula success.[15] Chiang and colleagues reported that a higher resistive index of the feeding artery is closely related to early AVF failure.[16] Similar to the result of our study, Mouquet and colleagues also reported that after brachial plexus block, brachial artery diameter and blood flow as well as AVF blood flow increased compared with controls.[17]

The use of regional anaesthesia, compared with other anaesthetic techniques such as general anaesthesia and infiltration anaesthesia, has been shown to result in higher patency rates.[11] USG brachial plexus block allows more accurate placement of the injection needle, which can allow more rapid onset and longer duration of the block as well as reducing vascular and neurologic complications and reducing the volume of local anaesthetic required to achieve a successful block.[2,18,19] We achieved 100% success rate and no complications related to the USG supraclavicular block technique, which supports the notion that USG injection is a simple and safe technique in performing supraclavicular brachial plexus block. Lehtipalo and colleagues reported that interscalene brachial plexus

block reduces regional sympathetic nervous activity, resulting in increases in skin blood flow, skin temperature and attenuated vasoconstrictor responses.[20] Johnson and colleagues reported that radiocephalic fistulas with a postoperative flow rate of 170 ml/min were at risk of early failure. In our study it was approximately 295 ml/min at 30 min after surgery.[21]

Ropivacaine is safe in renal failure. Although a metabolite of ropivacaine (pipecoloxylidide) may accumulate in plasma during long-term postoperative infusions, in particular in patients with coexisting low non-renal elimination, its systemic toxicity is markedly less than ropivacaine.[22]

Since the systemic haemodynamic in both groups was comparable, differences in Doppler vascular parameters across the fistula were assumed to be due to a local fistula effect and sympathetic blockade by brachial plexus block.

Limitations
There was minor variability in Doppler ultrasound vascular parameter readings with each measurement. However, we took the average value of at least three readings after proper stabilisation of the probe over measurement sites.

Conclusion
In this prospective, randomised open level study, we have compared two regional anaesthetic techniques and have evaluated their effects on AVF blood flow and patency rate in an Indian population with ESRD. We observed that USG supraclavicular brachial plexus block was much better for arteriovenous fistula flow characteristics including diameter, PSV, blood flow and patency as compared with local infiltration anaesthesia.

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