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WRIST & HAND

Fixation of distal radius fractures using wide-awake local anaesthesia with no tourniquet (WALANT) technique

A RANDOMIZED CONTROL TRIAL OF A COST-EFFECTIVE AND RESOURCE-FRIENDLY PROCEDURE

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Aims

We hypothesized that the wide-awake local anaesthesia with no tourniquet (WALANT) technique is cost-effective, easy to use, safe, and reproducible with a low learning curve towards mastery, having a high patient satisfaction rate. Furthermore, WALANT would be a suitable alternative for the austere and developing operative environments where lack of funds and resources are a common issue.

Methods

This was a randomized control trial of 169 patients who required surgery for closed isolated distal radius fractures. The study was performed between March 2016 and April 2019 at a public sector level 1 trauma centre. General anaesthesia was used in 56 patients, Bier's block in 58 patients, and WALANT in 55 patients. Data were collected on pre-, peri-, and postoperative parameters, clinical outcome, hospital costs, and patient satisfaction. One-way analysis of variance (ANOVA) was used with a p-value of 0.05 being significant.

Results

Operations with WALANT proceeded sooner, and patients recovered faster, resulting in mean fewer missed working days (7.8 (SD 1.67)) compared with general anaesthesia (20.1 (SD 7.[illegible]) or Bier's block (14.1 (SD 7.65)) ($p < 0.001$). The WALANT patients did not develop complications, while the other patients did ($p < 0.04$). Clinical outcomes did not differ, nor did surgeon qualification affect clinical outcomes. Mean hospital costs were lower for WALANT ($528.50 (SD 77.71)) than for general anaesthesia ($630.63 (SD 114.77)) or Bier's block ($734.00 (SD 37.54)) ($p < 0.001$). Patient satisfaction was also higher ($p < 0.001$).

Conclusion

WALANT for distal radius fractures results in a faster recovery, is more cost-effective, has similar clinical outcomes, and has fewer complications than general anaesthesia or Bier's block. This makes WALANT an attractive technique in any setting, but especially in middle- and low-income countries.

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Keywords: Distal radius fracturex, WALANT, Anaesthesia, Wide-awake, Tourniquet

Article focus

- The wide-awake local anaesthesia with no tourniquet (WALANT) technique for distal radius fractures is cost-effective, easy to use, safe, and has a high patient satisfaction rate compared with general anaesthesia and Bier's block.
- WALANT is a great surgical skill that is reproducible and does not have a high learning curve or involve costly instruments.

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Key messages

- Application of the WALANT technique for anaesthesia during surgery for distal radius fractures results in a faster recovery, is more cost-effective, has similar clinical outcomes, and has fewer complications than general anaesthesia or Bier's block.
- Patient satisfaction is also higher for WALANT, making it an attractive overall alternative.

Strengths and limitations

- This was a randomized control trial with double blinding; we assessed WALANT with regional anaesthesia and general anaesthesia and no study to date, to our knowledge, has assessed the two techniques with WALANT in a single paper.
- The study was conducted in one institution only.

Introduction

Distal radius fractures are among the most common types of injuries encountered in orthopaedic traumatology and represent 17.5% of all fractures in the emergency department.[1] Fractures of the distal radius follow a bimodal pattern and are mainly found in children, active young adults following a high-energy trauma, and - as a result of osteoporosis - in the elderly.[2] They are treated with either splint stabilization or, for fractures that are unsta or cannot be treated with a cast, with surgery. Sin distal radius fractures hinder activities of daily life an thus affect an individual's financial circums early surgical intervention is also adopted to tre patien with high demand of the use of their hands suc s m writers, and doctors, and of patient ith h demand of the use of their time such as bu ss execut

The surgery can be perform u regional blocks such as brachial plexus blo or Bier's ock, or under general anaesthesia, wh a tourniquet applied to control haemostasis. H vever, applying blocks can be challenging and require h skill , while in general anaesthesia patie optim tion a prerequisite and sedation itself arrie risks. efore, a new method of anaesthe was eloped by Bezuhly et al,[3] which is widely know hand surgeons as wide-awake local anaesthesia with tourniquet (WALANT).

This local anae esia technique can be safely performed in an out-patient setting for hand surgery and requires no tourniquet or sedation, only injection of lidocaine and epinephrine in the surgical field.[4,5] The lidocaine is for anaesthesia, and the epinephrine provides haemostasis, which deletes the need for a tourniquet. In addition, this technique has the advantage that it can be used in patients who are normally denied surgery because of age, comorbidities, or other contraindications. The technique does not require stringent intraoperative monitoring and has been shown to improve results, cost-effectiveness by reducing the extensive preoperative workup before surgery, and patient satisfaction for various types of hand surgery by eliminating tourniquet-related pain.[6-9] Due to these advantages, the WALANT technique has quickly become a widely used anaesthesia technique for hand surgery.[10,11]

The WALANT technique has only recently been applied for distal radius fractures.[12-14] For distal radius fractures, one might assume that the same advantages of WALANT exist as for hand surgery, but this has not been extensively investigated. Only one article, by Huang et al,[15] has so far compared the use of WALANT for distal radius fractures with another anaesthesia technique. In that study, perioperative parameters and clinical outcomes were compared between WALA eneral anaesthesia with a tourniquet in 47 tients. found that the operation could begin mu sooner h WALANT than with general anae esia. A ough WALANT led to greater blood loss s wa a sm mount that did not raise concern. m important advantages of WALANT were th it le less operative pain and shorter hospit ation.[15]

We hypo es d that WA NT for distal radius fractures is cost-effect easy to use, safe, and has a high patie isfaction compared with the current pra ces of anaesthesia (general anaesthesia and Bier's blo). Furthe ore, we hypothesized that WALANT is a re ducible echnique and does not require a high skillset these hypotheses, we compared various perioperative parameters, clinical outcome, and costs o l anaesthesia, Bier's block, and WALANT techques in a prospective cohort study.

Methods

A randomized controlled study with the intention to treat was conducted to compare various perioperative parameters, clinical outcome, and costs between three anaesthesia options (WALANT, general anaesthesia, and Bier's block) for surgery of distal radius fractures (Figure 1). The study was conducted at a public sector tertiary care level 1 trauma centre between March 2016 and April 2019. The study protocol was approved by the medical ethics review (institutional review board (IRB) approval: NO.F.2 to 81/GENL-2016/11183Ab/JPMC) and all procedures followed were in accordance with the Helsinki declaration. The study was registered in an open access registry, namely the Chinese Clinical Trial registry under the trial number ChiCTR1900026870.

Study design. A total of 169 patients with an isolated closed fracture of the distal radius who presented to our hospital within ten days of the initial injury were included; the demographics of the cohorts are stated in Table I. Exclusion criteria consisted of open fractures of the distal radius, bilateral distal radius fractures, active infection in the body, and certain contraindications to WALANT as expressed in Table II.

Anteroposterior and lateral radiographs of the wrist were obtained on the first presentation to the orthopaedic emergency department, and the fracture was

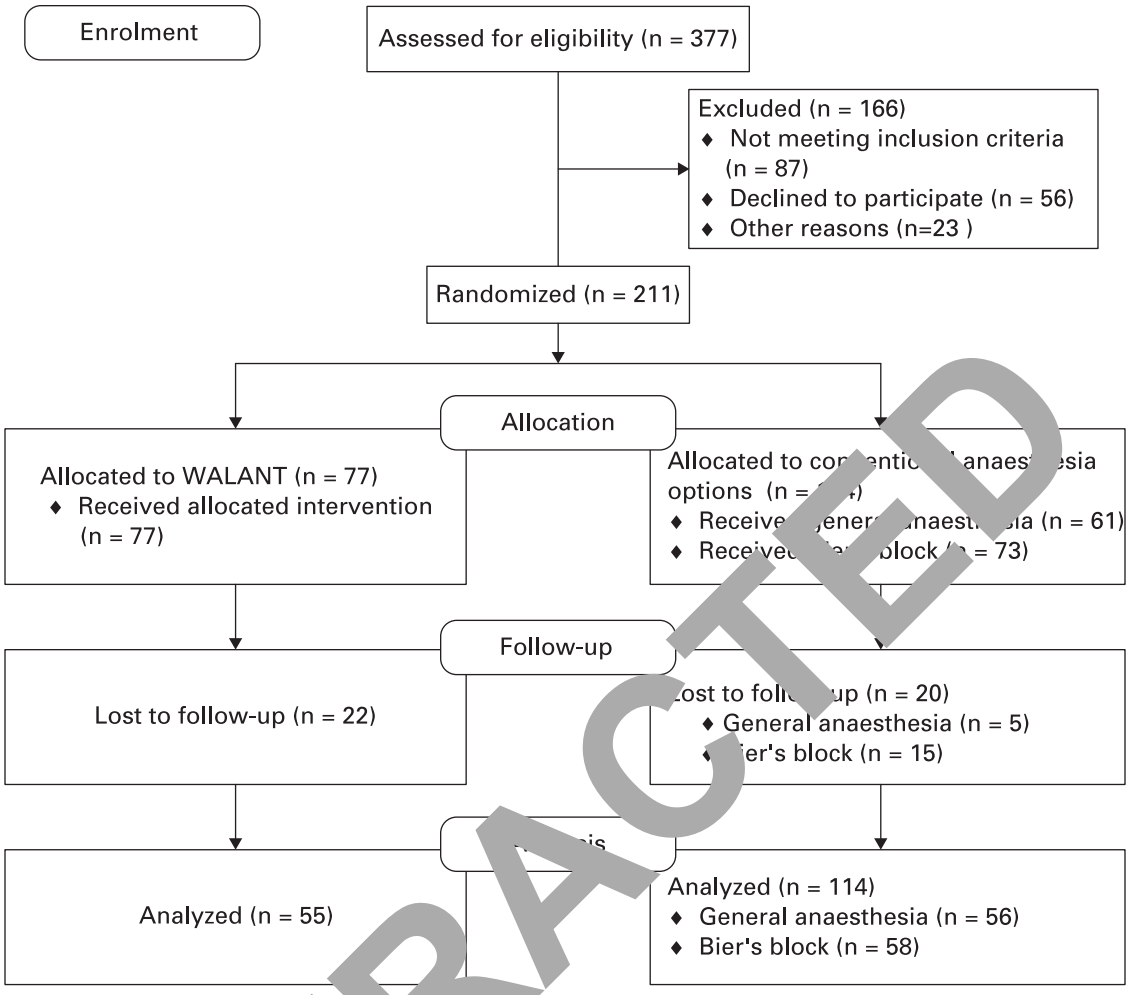

Fig. 1

CONsolidated Standards Of Reporting Trials (CONSORT) flow diagram. WALANT, wide-awake local anaesthesia with no tourniquet.

classified according to the Orthopaedic Trauma Association (OTA) classification system.[16]

Patients were informed about the conservative and surgical treatment options, and patients opting for operative management were further informed about the trial and the risks of the surgery, including the three anaesthesia options (general anaesthesia, Bier's block, and WALANT). The fitness of patients for surgery was determined by the anaesthesiologist before the operation, based on the classification system of the American Society of Anesthesiologists (ASA).[17,18]

A system-generated randomization algorithm was created by the research office and delivered by a dedicated officer to ensure that the allocation sequence was concealed. The individual patient was allocated treatment on a non-probability consecutive basis. When a patient entered the trial, a serial number was allotted to the patient. Double blinding technique was used and neither surgeon nor patient knew the intervention to be used prior to surgery; this was revealed in the operating theatre just before the surgery. The power of the study was kept at 80%.

The primary outcomes of the study were the patient's experience of pain and cost-effectiveness, which were divided into direct cost of the procedure and indirect cost along with the patient's intraoperative and postoperative experience, whereas the secondary outcomes were to compare the functional results of the surgery and patient satisfaction. The tertiary outcome was to investigate the reproducibility of the WALANT technique by comparing results of senior surgeons with the trainees.

Surgical technique - WALANT. Patients undergoing WALANT were briefed about the procedure in detail, especially about the multiple skin pricks for WALANT solution infiltration, the possibility of converting to general anaesthesia, and the application of a tourniquet if haemostasis was not adequate. The patients were warned about the risk of the vasoconstrictive effect of epinephrine concerning digital ischaemia.

Table I. Demographics and fracture classification.

Variable	Anaesthesia technique			p-value
	General anaesthesia (n = 56)	Bier's block (n = 58)	WALANT (n = 55)	
Sex, n (%)				0.550*
Male	28 (50.0)	33 (56.9)	31 (56.4)	
Female	28 (50.0)	25 (43.1)	24 (43.6)	
Mean age, yrs (SD)	49.7 (9.30)	48.1 (9.16)	46.6 (10.81)	0.017†
Fracture type, n (%)				0.911‡
A2	5 (8.9)	7 (12.1)	6 (10.9)	
A3	7 (12.5)	5 (8.6)	5 (9.1)	
B1	6 (10.7)	6 (10.3)	11 (20.0)	
B3	9 (16.0)	7 (12.1)	5 (9.1)	
C1	7 (12.5)	7 (12.1)	7 (12.7)	
C2	9 (16.0)	12 (20.7)	15 (27.3)	
C3	13 (23.2)	14 (24.1)	6 (10.9)	
Dominant hand, n (%)	36 (64.3)	34 (58.6)	38 (69.1)	n.s.*

n.s., not significant; WALANT, wide-awake local anaesthesia with no tourniquet.
*Chi-squared test.
†One-way analysis of variance (ANOVA).
‡Fisher's exact test.

Table II. Contraindications for wide-awake local anaesthesia no tourniquet (WALANT) as exclusion criteria for this study.

Contraindications for WALANT
Absolute contraindication
Anxious and non-cooperative patients
Needle phobia
Peripheral vascular disease or active infection
Bleeding tendency
Abnormal clotting profile
Hypersensitivity to lidocaine
Relative contraindication
Polytrauma patients

We used the haematoma block method, for which 3 ml to 5 ml of 2% plain lidocaine was initially injected through the dorsal aspect of the fracture. For every 50 ml of WALANT solution we used 0.9% normal saline and 2% lidocaine with 1:1,000,000 concentration of epinephrine at a ratio of 1:1 (Figure 2). The surface anatomy of flexor carpi radialis (FCR) tendon was identified by radially deviating the wrist, and points were marked on the skin. In the same manner, the distal third of the radius was palpated, and four skin points were marked 2 cm apart starting from the distal wrist crease (Figure 3a). Proposed identification marks were prepared with povidone and chlorhexidine for subcutaneous local anaesthesia administration, according to the maximum safe dosage of 7 mg/kg/ml. The actual site was sterilized and prepared for surgery while the surgeon (MT, GM, EAC) waited for the haemostatic effect; surgery started when 30 minutes had passed since the administration of the WALANT solution or when the visual analogue scale (VAS) was zero,[18] or whichever came first (Figures 3b and 3c).

In order to decrease the patient's level of anxiety during the surgery, one dedicated staff member of the operating team (MT, GM, KA, EAC) was designated to provide distractive anaesthesia to the patient by talking and providing distraction, especially during the drilling of the periosteum. Henry's approach was used in all cases and the procedure started with a longitudinal incision over the volar wrist.[19] Pronator quadratus (PQ) was exposed afteridentification, and the FCR and flexor pollicis longus (FPL) were retracted towards the ulna. An additional 5 ml of the WALANT solution was injected beneath the PQ to anesthetize the periosteum, and the surgery was paused for approximately 30 seconds for the local anaesthesia to take effect (Figure 3d). PQ was reflected from radial attachment for fracture reduction, plate placement, drilling, and screw fixations (Figure 3e). Locking plates (Double Medical Technologies, Fujian, China) were used in all cases.

The patient's vital signs, bleeding, and VAS score were recorded every ten minutes throughout the surgery. Blood loss was calculated according to the amount of blood present in the suction container. Fracture reduction was checked under a fluoroscope, during which the patients were asked to actively flex and extend their wrists and fingers to examine the stability of the fixation and identify any tendon disorders before wound closure (Supplementary Video i). The skin was sutured with simple interrupted nylon 2 to 0 sutures (Ethicon, Johnson & Johnson, Somerville, New Jersey, USA) and a soft dressing was applied.

Surgical technique - general anaesthesia and Bier's block. Patients having general anaesthesia or Bier's block with a tourniquet underwent a series of preoperative examinations and an anaesthesia risk evaluation. After adequate preparation, the patients received general anaesthesia or Bier's block under careful monitoring by the anaesthetist. A pressure of 250 mm Hg was applied via a tourniquet to limit blood loss. Surgery was performed according to the same approach used for the patients having WALANT.

Postoperative care. For all patients operated on, vital signs and VAS score were obtained every half-hour after the surgery and the patients were kept in the ward overnight and discharged the next day. After the tenth WALANT procedure, the protocol for WALANT changed to day care surgery and patients were discharged after eight hours unless patients insisted on staying overnight. After the change in the WALANT protocol patients were informed of the signs and symptoms of compartment syndrome, digital ischaemia, and discharge from the wound site, and they were instructed to report immediately to

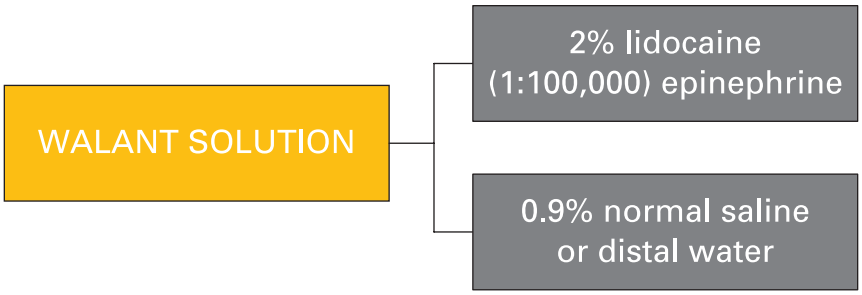

Fig. 2

Composition of wide-awake local anaesthesia with no tourniquet (WALANT) solution mixed in ratio of 1:1.

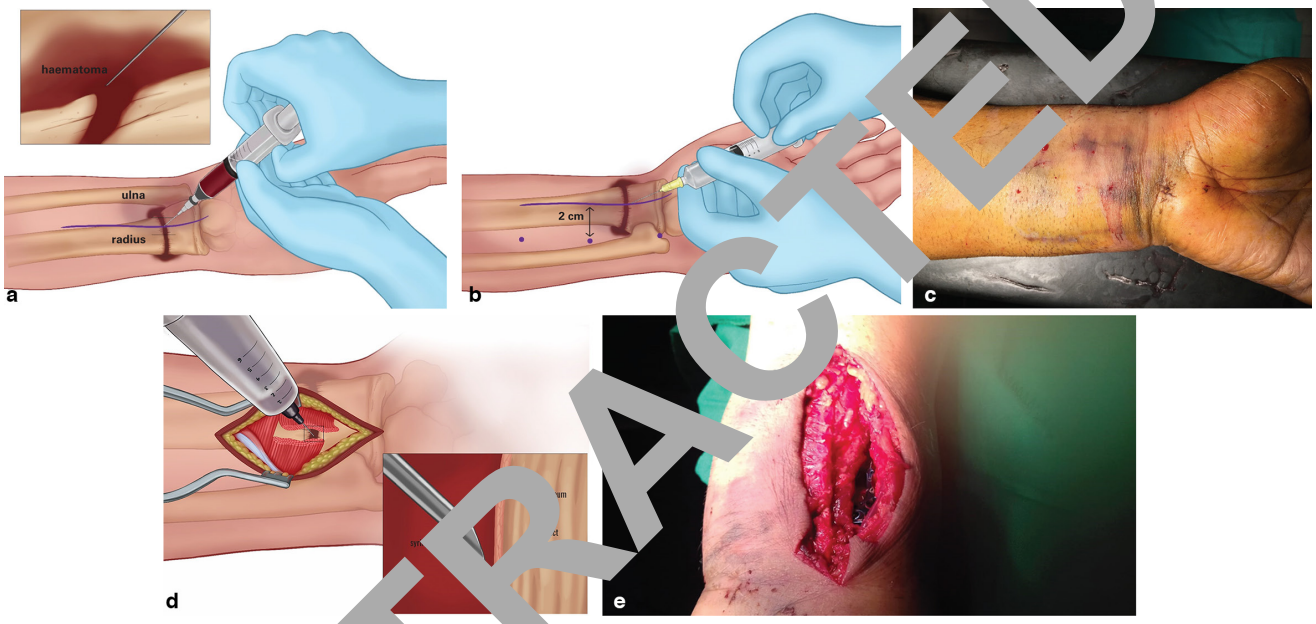

Fig. 3

a) Haematoma block (2% lidocaine); b) Skin infiltration (subcutaneous plane) with wide-awake local anaesthesia with no tourniquet (WALANT) solution. c) Tumescent effect of WALANT solution. d) Periosteal block; e) Final implant position and surgical exposure.

the orthopaedic emergency ward of the hospital should any of the symptoms develop.

For each patient, oral tramadol 37.5 mg/325 mg acetaminophen combination tablets two times a day were prescribed as the protocol for postoperative pain control medication, along with calcium supplements. In all three groups the patients were encouraged to practice flexion and extension as per tolerance to pain, and none of the patients' wrists were immobilized.

The first follow-up visit was two weeks after the surgery. Follow-up was performed in the outpatient clinic along with a follow-up visit to the physiotherapist for range of movement and grip strengthening exercises. Fracture union was assessed radiologically with the union of three out of four cortices, the range of movement was recorded by a goniometer, and patient satisfaction was evaluated by 12-Item Short-Form Health Survey questionnaire (SF-12)[21,22] at six weeks and one year. For the functional evaluation of the wrist the quick Disabilities of the Arm, Shoulder, and Hand (qDASH) questionnaire, Mayo's score, and patient-rated wrist evaluation (PRWE)[23] were assessed at one year.[24-26] Patients were followed up for one year.

The patients were advised to take a minimum of five days of rest and were then allowed to resume work according to their convenience, and were enrolled in a continuous physical therapy programme. Since most of the patients were on daily wages, they were allowed to do light duty work if they demonstrated half of the grip strength compared with the contralateral wrist. However, extended rest was prescribed depending on clinical and subjective assessment and taking into consideration the nature of the patient's work.

Table III. Perioperative and postoperative data.

Variable	Anaesthesia technique			p-value*
	General anaesthesia (n = 56)	Bier's block (n = 58)	WALANT (n = 55)	
Mean time to surgery, days (SD)	6.89 (3.58)	4.31 (3.62)	1.22 (1.44)	< 0.001
ASA grade before operation, n (%)				< 0.001†
1	13 (23.2)	16 (27.6)	17 (30.9)	
2	23 (41.1)	20 (34.5)	12 (21.8)	
3	12 (21.4)	13 (22.4)	12 (21.8)	
4	8 (14.3)	9 (15.5)	14 (25.5)	
Mean preoperative time, mins (SD)	33.7 (5.81)	30.2 (4.67)	23.0 (3.85)	< 0.001
Mean operative time, mins (SD)	68.8 (14.97)	65.5 (12.61)	61.3 (9.28)	0.018
Conversion to general anaesthesia, n	N/A	4	2	0.693‡
Mean intraoperative top-up dose, ml (SD)	N/A	8.0 (7.49)	4 .47)	< 0.01
Mean blood loss, ml (SD)	11.5 (4.25)	14.0 (4.89)	4 (8.50)	< 0.001
Mean recovery time, mins (SD)	21.4 (3.98)	20.6 (5.34)	1 .35)	< 0.001
Mean highest intraoperative VAS score (SD)	N/A	4.4 (1.04)	3.5 (	< 0.001§
Mean VAS score at 24 hrs after operation (SD)	3.0 (1.24)	2.2 (1.35)	2 (0.62)	< 0.001
Mean hospital stay, days (SD)	1.2 (0.78)	1.5 (0.99)	0.2 (0.50)	< 0.001
Mean ICU stay, days (SD)	0.2 (0.52)	0.2 (0.72)	0	0.238
Mean daily frequency of oral analgesics (SD)	2.3 (0.61)	2.0 (0	(0.59)	< 0.001
Mean time oral analgesics used, days (SD)	12.4 (3.35)	10 .6	.0 (2.04)	< 0.001
Mean number of physiotherapy sessions (SD)	13.4 (6.36)	10.1 (6.13)	5.5 (1.10)	< 0.001
Patients with complications, n	3		0	0.032

*One-way analysis of variance used unless indicated otherwise.
†Chi-squared *t*-test.
‡Fisher's exact test.
§Independent-samples *t*-test.
ASA, American Society of Anesthesiologists; ICU, intensive care uni ot applica s., not significant; VAS, visual analogue scale; WALANT, wide-awake local anaesthesia with no tourniquet.

Cost comparisons. The direct and indire cos procedures that were measured we l) ho al costs, such as number of people in the atre, imp t cost, recovery time, number of days nig dependen y unit (HDU), and total number of ays in ho al; and 2) patient costs, such as numb of analgesics ed, number of physiotherapy sessi s, an umber of days lost.

Parameters measur peri eratively and postoperatively. Pera p ameters measured included prep tio me, o ting time, blood loss, conversion the edure to general anaesthesia, top-up dose ed, in operative VAS scale (pain scale), immedia ostoperative VAS, VAS at 24 hours, high level of care re ired, and complications. Patient satisfaction was determined with a SF-12 questionnaire at six weeks and one year.

Clinical outcomes at one year of surgery. Clinical outcomes were determined at one year after the operation. The objective outcomes included wrist extension and flexion, Mayo wrist score, grip strength in newtons, the qDASH questionnaire that was filled in by a doctor on the surgical team, and PRWE questionnaires that were filled in by the patients.

Statistical analysis. All data were entered into a database and analyzed with SPSS v26 (IBM, Armonk, New York, USA). GraphPad Prism 8 (GraphPad Software, San Diego, California, USA) was used to analyze a subset of the data and prepare graphs. One-way analysis of variance (ANOVA) and independent-samples *t*-tests were used to compare continuous variables and chi-squared tests were used to compare categorical variables, as appropriate. A p-value of less than 0.05 was considered to be statistically significant.

Results

The WALANT technique proved to be safe and more cost-effective than general anaesthesia and Bier's block, ergonomically and logistically. In addition, patients operated in the WALANT group experienced a faster recovery and had similar clinical outcomes at one year of follow-up compared with patients operated under general anaesthesia and Bier's block.

Moreover, the results of this trial strongly suggest that the WALANT technique had a small learning curve towards mastery and when the patient's clinical outcomes were compared between junior and senior doctors no statistical significance was observed, and this further strengthened the notion that WALANT is a reproducible technique.

Primary outcomes. A primary outcome of this study was cost-effectiveness. Operations with WALANT proceeded sooner than operations with other techniques (p < 0.001,

Table IV. Patient satisfaction and cost comparison.

Variable	Anaesthesia technique			p-value*
	General anaesthesia (n = 56)	Bier's block (n = 58)	WALANT (n = 55)	
Mean patient satisfaction after 6 wks (SD)	32.0 (8.28)	36.0 (8.04)	42.2 (2.29)	< 0.001
Mean patient satisfaction after 1 yr (SD)	37.6 (6.75)	40.8 (6.02)	44.82 (1.38)	< 0.001
Patient would undergo same procedure again, n (%)	47 (83.9)	50 (86.2)	53 (96.4)	< 0.001†
Mean hospital cost, $ (SD)	630.63 (114.77)	734.00 (37.54)	428.50 (77.71)	< 0.001
Payment method, n (%)				0.017
Out of pocket	14 (25.0)	26 (44.8)	26 (47.3)	
Insurance policy	11 (19.6)	14 (24.1)	9 (16.4)	
Welfare/charity	31 (55.4)	18 (31.0)	20 (36.4)	
Number of people in the operating room	5.9 (0.37)	5.1 (0.93)	4.1 (0.32)	< 0.001
Mean time to return to work after surgery, days (SD)	13.2 (5.15)	9.72 (4.81)	7.7 (1.1)	< 0.001
Mean total working days lost due to injury (SD)	20.1 (7.37)	14.1 (7.65)	7.8 (1.67)	< 0.001

*One-way analysis of variance (ANOVA) used unless indicated otherwise.
†Chi-squared test.
WALANT, wide-awake local anaesthesia with no tourniquet.

one-way ANOVA), with a substantially higher percentage of patients having a poor physiology and higher anaesthesia risk prior to operation in the WALANT technique group than in either of the other two technique groups (p < 0.001, chi-squared test) (Table III).

Similarly, the mean preparation time for the surgery was longer for the general anaesthesia group (33.7 minutes (SD 5.81)) and the Bier's block group (30.2 minutes (SD 4.67)) than for the WALANT group (23.0 m (SD 3.85)) (p < 0.001, one-way ANOVA). However, the operating time did not differ much between the te niques (p < 0.018, one-way ANOVA) whil ery ti was significantly shorter for the WALA techn ue (p 0.001, one-way ANOVA) (Table III).

Due to pre-existing comorbid ditio nd a higher ASA grade, postoperatively th aesthetis cided to put five of the general anae esia d four of the Bier's block patients in an inte e care u CU), while none of the WALANT patien equired ICU st (Table III).

The mean numb of to days in the hospital was different between th e gro s, with the general anaesthesia g the ier's lock group, and the WALANT gr p st ng fo (SD 0.78), 1.5 (SD 0.99), and 0.2 d (SD 0) respectively (p < 0.001, one-way ANOVA) (Ta).

The WALAN roup consumed mean fewer analgesics and required me fewer physiotherapy sessions (p < 0.001, one-way ANOVA) (Table III). The decision to end the physiotherapy session was decided by a multidisciplinary meeting with the patient, which included the operating surgeon and the physiotherapist, and patients were instructed to carry physiotherapy exercises at home.

There was a significant difference in mean costs between the procedures (p < 0.001), with Bier's block costing most at $734.00 (SD 37.54), general anaesthesia $630.63 (SD 114.77), and the WALANT technique costed the least at $428.50 (SD 77.71) (Table IV). Each of these costs included the costs of the implants, the costs of the actual operation, hospital stay, and follow-up visits. Of all 169 par pants in e s dy, only 34 (20.1%) had an insura e olicy that d the costs, 66 participants (39.1%) had to y out-of-pocket, and 69 (40.8%) relied on re (Table

Aside from the hospital costs, the patients also lost ys at wor which in most cases affected their income as t majorit orked on daily wages. The number of days fro e of surgery to resumption of work differed significantly between the three groups (p < 0.001, one-ANOVA) (Table IV). Since most people also lost working days from the time of injury to the operation, the mean total number of working days lost was even greater: 20.1 days (SD 7.37) for the general anaesthesia group, 14.1 days (SD 7.65) for the Bier's block group, but only 7.8 days (SD 1.67) for the WALANT group, and this difference was also significant (p < 0.001, one-way ANOVA) (Table IV).

Clinical effectiveness was another primary outcome of this study. During the operation the WALANT patients scored better on the intraoperative VAS (p < 0.001, independent-samples *t*-test), with a mean highest intraoperative VAS score of 3.5 (SD 0.78) compared with 4.4 (SD 1.04) for the Bier's block patients.

Likewise, 24 hours postoperatively the WALANT patients also scored better on the VAS with a mean score of 1.2 (SD 0.62) compared with 3.0 (SD 1.24) and 2.2 (SD 1.35) for the general anaesthesia and Bier's block patients, respectively (both p < 0.001, one-way ANOVA). The mean VAS score between the general anaesthesia and Bier's block groups differed only slightly (p < 0.02) (Table III).

Patient satisfaction with the procedure was highest for the WALANT group, both at six weeks and one year after the procedure (both p < 0.001, one-way ANOVA). When asked whether, should the situation arise, the patient would consider choosing the same anaesthesia procedure again for removal of implant or recommend the same procedure again to someone, 53 (96.4%) patients in the WALANT group said yes, compared with just 47

Table V. Clinical outcomes at one year after operation.

Variable	Anaesthesia technique			p-value*
	General anaesthesia (n = 56)	Bier's block (n = 58)	WALANT (n = 55)	
Mean time to bone union, wks (SD)	15.8 (2.54)	15.3 (2.60)	15.3 (2.31)	0.763
Mean wrist extension, ° (SD)	52.9 (4.45)	53.4 (4.95)	54.8 (6.45)	0.428
Mean wrist flexion, ° (SD)	64.3 (4.47)	64.4 (4.92)	65.9 (6.01)	0.649
Mean Mayo wrist score (SD)	87.3 (5.13)	87.9 (4.66)	86.3 (5.08)	0.213
Mean grip strength, N (SD)	74.3 (8.42)	74.0 (8.81)	73.6 (7.35)	0.537
Mean qDASH questionnaire score (SD)	10.2 (2.99)	8.8 (2.90)	10.2 (2.80)	0.050
Mean PRWE questionnaire score (SD)	9.6 (3.54)	12.6 (4.20)	9.8 (3.35)	< 0.001
Functional stratification, n (%)				n.s.†
Excellent	25 (44.6)	37 (63.8)	28 (50.9)	
Good	28 (50)	21 (36.2)	25 ( )	
Fair	3 (5.4)	0	2 ( )	

n.s., not significant; PRWE, patient-rated wrist evaluation; qDASH, quick Disabilities of the Arm, Shoulder, an Hand, LANT, wi awake local anaesthesia with no tourniquet.
*One-way analysis of variance (ANOVA) used unless indicated otherwise.
†Fisher's exact test.

(83.9%) and 50 (86.2%) patients from the general anaesthesia and Bier's block groups, respectively (p < 0.001, chi-squared test) (Table IV).

Secondary outcomes. Clinical outcomes did not differ between the three groups, nor did the time from operation to bone union (Table V). However, patients in the WALANT group had a higher mean intraoperative blood loss than patients in the other two groups (p < 0.0 one-way ANOVA) (Table III).

Complications were encountered in three patient in the general anaesthesia group who dev attrition injury (one) and mild inflammation the ound (two), and in three patients of the Bier's b gr developed tourniquet palsy (two) du to tig urniquet application and local anaesthetic temic (LA oxicity (one). No complications were se in the W LANT group (Table III).

During the operation was decided the anaesthesia procedure of f (6.9 %) of the Bier's block patients and two (3.64% f e WAL NT patients had to be changed to ge ana hesi ue to anxiety.

Tertiary outc es. qua tion of the surgeon did not affe he cli al outcomes; of the 55 WALANT procedures, 2 ca out by one of five consultants and 35 we arried out by one of five residents (Supplementary Ta).

Discussion

In this randomized controlled study, we found that the WALANT anaesthesia technique applied during operation on distal radius fractures leads to a faster recovery, is more cost-effective, has similar clinical outcomes, and has fewer complications than general anaesthesia or Bier's block. In addition, we found that patient satisfaction is much higher for WALANT than for general anaesthesia or Bier's block. Together, these factors make the WALANT technique an attractive alternative for patients who qualify for this technique.

The WAL echnique been in use for hand and wrist surgery a number of years,[7,10,11] and it was found WALAN much more cost-effective than gen anaesthesia. In a USA study comparing the costs of LANT ve s general anaesthesia for carpal tunnel syn me surg y, a mean saving of $1,320 on healthcare c ch included anaesthesia cost, preoperative cost, and postoperative cost - was found.[27]

st comparison has been reported yet for WALANT sus any other technique for surgery of distal radius fractures. In our study, hospital costs were determined mong others by factors such as length of hospital stay, number of complications, and number of people in the operating room. These factors all turned out to be more favourable for the WALANT group and resulted in mean total hospital costs of $428.50 (SD 77.71).

The difference in cost between WALANT and general anaesthesia ($202.10), as well as between WALANT and Bier's block ($305.50), is considerable, although these differences are much smaller than the difference of $1,320 between WALANT and general anaesthesia for carpal tunnel syndrome, most likely because healthcare costs in Pakistan are in general much lower than those in the USA.[27] To put the mean total hospital cost range of $428.50 to $734.00 for the three procedures into perspective, it is relevant to know that the mean annual household income in 2016 in Pakistan was $651.[28]

The WALANT technique was only last year reported as an anaesthesia option for surgery of distal radius fractures.[12-14] The technique and one case were first described by Ahmad et al,[12] and Orbach et al[13] subsequently described successfully operating on five cases. Orbach et al[13] concluded that the WALANT technique offers a simple and safe alternative to traditional anaesthetic techniques for surgery on distal radius fractures.

In a subsequent study on 47 patients comparing WALANT with general anaesthesia for distal radius fractures, Huang et al[15] found that the patients undergoing

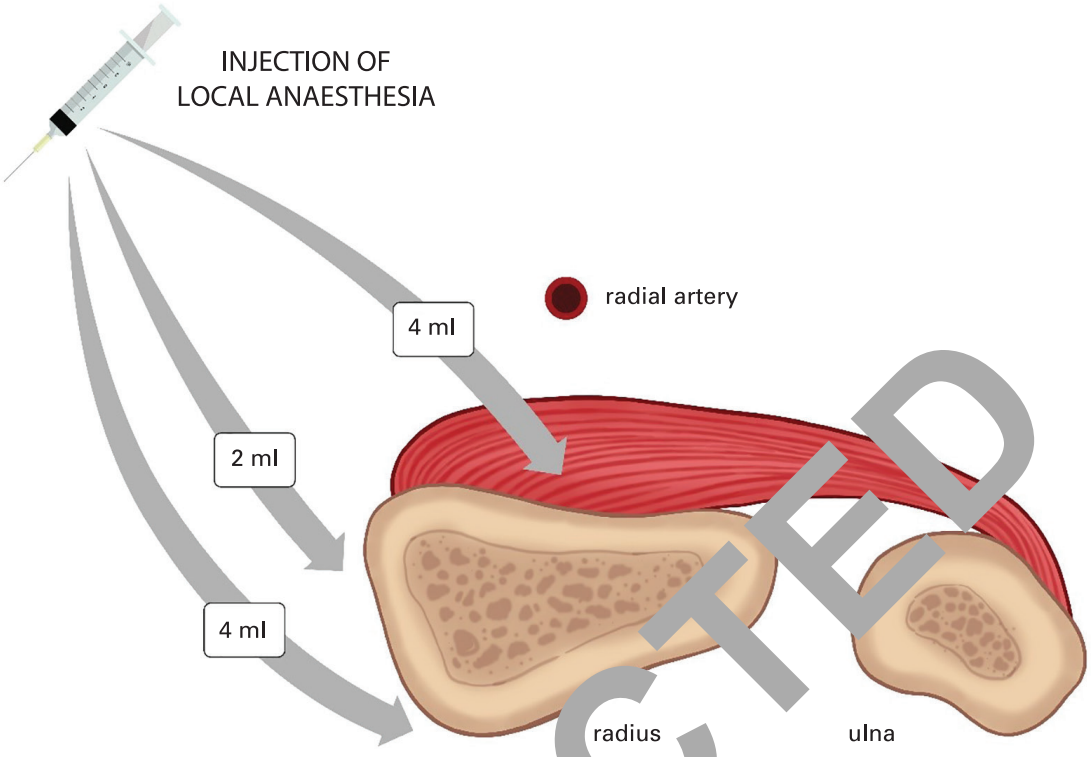

Fig. 4

Cross-sectional anatomy of the distal radius.

WALANT anaesthesia lost more blood th gene anaesthesia patients (23 ml vs 9 ml) t we in les pain, and that the clinical outcomes addition, no complications for ner nique were reported, making WALANT a f le and e tive technique to apply for surgery c ista dius fractures.[15] We also found that althoug WALANT tients lost more blood (23.4 ml) than patients in t general anaesthesia and Bier's blo roup (12 ml and 14 ml), the total amount lost was no or co ern.

In our stud WA NT nique resulted in no complicatio co ared the general anaesthesia or Bier's k tec ques (three and three, respectively). The WALAN nique not difficult to perform, based on the reprod ility of the technique between consultants and reside (Supplementary Table i).

The three techniques resulted in similar clinical outcomes, but since the WALANT technique resulted in a faster recovery, WALANT may be an attractive alternative to general anaesthesia and Bier's block. The patients in the WALANT group lost fewer working days as they recovered faster from the operation but - most importantly - because the time from injury to operation was much shorter. One of the main reasons for early return to (light duty) work was the psychological empowerment of the patient during the WALANT procedure, as the patient was able to flex and extend the wrist intraoperatively; this created a placebo effect and empowered the patient.

In terms of cost-effectiveness, WALANT does not require the advanced skills or resources such as a portable ultrasound machine or an anaesthetist that are required for Bier's block, or the increased logistics that are necessary for general anaesthesia; it can be treated as local anaesthesia, which is cost-effective and resource-friendly to the hospital and the patient. As a result, the operation could often be scheduled on the same day.

Since the mean recovery time was shorter in the WALANT group, hospital costs and other costs for the patients were lower than those for the general anaesthesia and Bier's block groups. Due to this faster recovery, direct patient costs such as number of physiotherapy sessions and analgesics use were lower in the WALANT group. A very important cost factor for patients may have been the number of working days lost, as for most people in Pakistan loss of working days means loss of income.

Based on studies applying WALANT for hand and wrist surgery, it is known that patients operated on with the WALANT technique score high on patient satisfaction (reviewed in van Demark RE et al[29]), with many (86%) saying they would choose the same technique again and 90% saying they would recommend it to a friend.[30] In our study, around 96% (n = 53) of the WALANT group said they would undergo the same procedure again if needed, as opposed to 83.9% (n = 47) and 86.2% (n = 50) for the general anaesthesia and Bier's block groups. Patient satisfaction was also

significantly higher in the WALANT group at both six weeks and one year after surgery than in the other two groups.

Indeed, Huang et al[15] also addressed the same intervention as ours; however, the current study has a larger sample size, almost three times that of the aforementioned study. Furthermore, Huang et al[15] focused on clinical outcomes, whereas our study comprehensively addressed costs, patient satisfaction, and clinical outcomes in a more detailed manner.

In addition, WALANT is a novel technique for treating distal radius fractures, so there is a need for further studies of this technique. The literature still requires additional outcomes to establish its effectiveness. These factors warrant the publication of this study as level I evidence.

In conclusion, application of the WALANT technique for anaesthesia during surgery for distal radius fractures results in a faster recovery, is more cost-effective, has similar clinical outcomes, and has fewer complications than general anaesthesia or Bier's block. This makes WALANT an attractive anaesthesia technique in any setting and is a great skill for the surgeon to be equipped with. Patient satisfaction is also higher for WALANT, making it an overall attractive alternative.

The first limitations of the WALANT approach are patient selection and local anaesthesia administration. Furthermore, appropriate knowledge of the surface anatomy of the distal radius is an essential prerequisite for the success of the technique, as the administration of local anaesthesia depends on the anatomical locations, especially when infiltrating the periosteum for drilling. In this scenario, the radial artery is nearby and, if the radial border and injecting laterally to the radial border injury to the radial artery can be avoided. Also, for the periosteal block to work effectively, the needle should go under the periosteum without being removed, and by circumferentially moving the needle the dorsal and volar sides can be infiltrated using WALANT solution (Figure 4). This would also minimize pain when manipulating the fracture near the radial border of the distal radius.

Secondly, patients should be counselled in details regarding the WALANT technique, especially multiple needle pricks. Also, in our experience extreme levels of anxiety should be considered as an absolute contraindication.

Finally, we stress patience and tolerance from the surgeons' side to be the key factor for a successful WALANT procedure, especially the importance of allowing 25 to 30 minutes before the commencement of surgery to establish adequate anaesthesia and vasoconstriction.

Supplementary material

Video showing the fixation of distal radius fracture under wide-awake local anaesthesia with no tourniquet (WALANT).

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