Comparison of three different methods of radial artery cannulation: a prospective randomized study

PROJECT
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DECLARATION

I hereby declare that this thesis entitled "**Comparison of three different methods of radial artery cannulation: a prospective randomized study**" has been prepared by me under the able guidance of Prof. Prasanta Kumar Dash, Division Of Cardiothoracic And Vascular Anaesthesia, Department Of Anaesthesiology, at Sree Chitra Tirunal Institute For Medical Sciences & Technology, Thiruvananthapuram.

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CERTIFICATE

This is to certify that this thesis entitled **“Comparison of three different methods of radial artery cannulation: a prospective randomized study”** has been prepared by Dr Suddhadeb Roy, DM Cardiothoracic and Vascular Anaesthesiology Resident, Division of Cardiothoracic and Vascular Anaesthesiology at Sree Chitra Tirunal Institute for Medical Sciences & Technology, Thiruvananthapuram. He has shown keen interest in preparing this project.

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Contents

List of Abbreviations

- USG – Ultrasonography
- SBP – Systolic blood pressure
- DBP – Diastolic blood pressure
- MAP – Mean arterial pressure
- CPB – Cardiopulmonary bypass
- BMI – Body mass index
- EF – Ejection fraction
- Premed – Pre-medication
- NIBP – Non-invasive blood pressure
- CAD – Coronary artery disease
- HR BL – Heart rate Before cannulation / Baseline
- NIBP Sys BL – Systolic Non-invasive BP Before cannulation / Baseline
- NIBP Dia BL – Diastolic Non-invasive BP Before cannulation / Baseline
- SpO_2 BL – Oxygen saturation Before cannulation / Baseline
- HR AC – Heart rate After cannulation
- NIBP Sys AC – Systolic Non-invasive BP After cannulation
- NIBP Dia AC – Diastolic Non-invasive BP After cannulation
- SpO_2 AC – Oxygen saturation After cannulation

Introduction

The insertion of radial artery cannula for continuous blood pressure measurement and blood sampling is almost universal in intensive care environment. The catheter is usually inserted by using a blind palpation technique, [1] although Doppler guidance method has also been employed.[2] However, the insertion of the radial artery catheter can sometimes be difficult, requiring multiple attempts which can cause patient discomfort and suffering.

Although the radial artery is usually much smaller than the central veins, it is easily identified by 2D ultrasound scanning— there it is seen as a pulsating black circle, on a background which is otherwise static and mainly white.

Ultrasound (US) has been associated with reduction of complications and improved first-pass success rate in multiple studies.[3-5] In one meta-analysis the reduction of complications was seen up to 57% and the reduction of failure to place the catheter was up to 86%.[5] The evidence is very convincing, so that the Agency for Healthcare Research and Quality (AHRQ) recommended the use of ultrasound for placement of central venous catheters (CVC) as one of their 11 standard practices to improve patient care.[6]

Although a number of clinicians have become comfortable with US-guided (USG) CVC access, fewer of them are familiar with placement of arterial catheters by USG guided techniques. Recent studies have shown the usefulness of ultrasound for this indication.

Utilizing a Doppler for the radial artery cannulation has been well described**.**[7-9] The exact location of the artery is identified by a change of Doppler tone to a higher pitch or loss of Doppler tones as tip of the cannula comes in contact and compresses the radial artery. The success rate of using this technique is shown to be around 90%, if used by experienced anaesthesiologists. None of the studies yet have compared the success rate of cannulation of US, Doppler and traditional palpation method. Therefore we in our present study aim to compare the 3 different approaches for radial artery cannulation in adults.

Aims and Objectives

Our primary aim is to compare the rate of successful cannulation of radial artery using different cannulation techniques.

Secondary Objectives:

We will also note the –

- First-pass success rate (rate of successfully cannulating the artery in the first attempt),
- Total number of attempts,
- The time taken to cannulate, and
- Any complication related to the procedure.

Review of Literature

❖ General Principles –

The measurement of arterial pressure waveform is ideally to be done in ascending aorta. The measurement of pressure in the distal peripheral arteries differs a bit from the pressure measured in the central aorta. As the pulse wave signal transmits down the arterial system distally, the arterial waveform gets more and more distorted. The distortions include – disappearance of certain high-frequency components, like the dicrotic notch; increase in the systolic peak pressure; decrease of the lowest diastolic point; and delay in transmitting the signal. Reduced peripheral arterial compliance can cause these changes, alongwith arterial tree pressure waves, which get reflected and resonated.[10] The dorsalis pedis artery shows this effect maximally, where the SBP is 10-20 mmHg higher and DBP is 10-20 mmHg lesser than the central aorta.[11] However, the measurement of MAP in peripheral arteries is generally same as that in central aorta. But this may not hold true after CPB.[12, 13]

❖ Anatomy of radial artery –

➢ In the forearm -

The radial artery originates from the brachial artery approximately at the neck of the radius and then passes along lateral aspect of the forearm. It lies just deep to the brachioradialis muscle, situated in the proximal half of the forearm.

In the distal part of forearm (Figure 1), radial artery is found immediately lateral to the flexor carpi radialis muscle tendon and also directly anterior to the pronator quadratus muscle and distal end of radius. So radial artery can be located in the distal forearm, by using the flexor carpi radialis as a landmark. The radial pulse is felt by gently palpating the radial artery in the distal forearm against the underlying muscle.

Leaving the forearm, the radial artery passes around lateral side of the wrist, and enters in the dorsolateral aspect of the hand, going in between the bases of metacarpals I and II. The branches of the radial artery in hand very often provide the major blood supply to thumb as well as the lateral side of index finger.

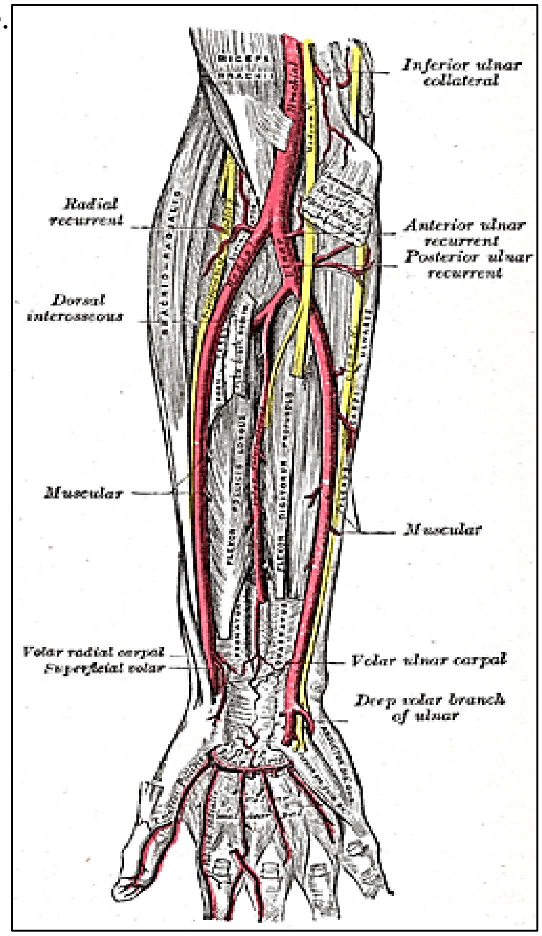

Fig -1: Anatomy of Radial artery in the forearm and wrist

Branches of radial artery originating in the forearm include:

- a radial recurrent artery, which forms an anastomotic network around the elbow joint and also to numerous vessels that supply the muscles on the lateral side of forearm
- a small palmar (volar) carpal branch which contributes to form an anastomotic network of vessels which supplies the carpal bones and joints

A somewhat larger branch, called the superficial palmar (volar) branch then enters the hand at the base of the thumb by passing through, or sometimes superficial to thenar muscles. It anastomoses with the superficial palmar arch which is formed by the ulnar artery.

- **In the wrist –**

The radial artery curves around the lateral side of wrist and passes over the floor of anatomical snuffbox. Then it enters the deep plane of palm by penetrating through the back of the hand anteriorly. It also passes between the two heads of the first dorsal interosseous muscle, and then between the two heads of adductor pollicis, to enter the deep plane of the palm and to form the deep palmar arch.

The deep palmar arch then passes medially through the palm in between the metacarpal bones and long flexor tendons of the digits. On the medial side of palm, it usually communicates with the deep palmar branch coming from the ulnar artery.

❖ Radial artery as cannulation site:

There are several factors which can influence the arterial cannulation site, e.g. the location, the obstruction to arterial flow due to patient position or surgery, any history of ischemia or history of a prior surgery. The surgical cutdown of proximal artery also can influence the choice of cannulation site. It may cause dampening of waveforms or false low BP due to stenosis or thrombosis. Axillary artery can be used by the surgeons for cannulation in CPB in patients requiring antegrade cerebral perfusion or with grossly diseased aorta,[14-16] though it can have possible complications like distal limb ischemia or limb excess circulation and systemic hypoperfusion.[17] For detection of the overcirculation of the arm, additional monitoring of radial artery on the same side has also been suggested.

Patients presenting for redo surgery also have some amount of stenosis at the previous cannulation site.

Radial artery is very commonly used for continuous invasive BP measurement. The advantages include its accessibility during surgery and ease of cannulation by a short catheter. It is important to check the adequacy of collateral circulation and rule out any obstructions proximal to it before cannulating the radial artery.

The Allen's test:

To perform this test, radial and ulnar arteries are compressed and the hand is exercised until it is pale. Then the ulnar artery is released and we note the time for the hand to regain its normal colour.[18] Normal colour is returned in the hand within 5 seconds, if the collateral circulation is normal. If the time taken is more than 15 seconds, then the cannulation of radial artery to that side may be avoided. However, if the fingers are hyperextended or widely spread apart, then the hand may continue to be pale, even if a normal circulation is present.[19] Alternatively, a Doppler probe or a pulse oximeter can be used to demonstrate collateral flow.[20-22] In case of compromised collateral circulation and unavailability of other cannulation sites, Ulnar artery can be cannulated**.**[23]

The Allen's test has questionable predictive value. In a study by Marshal et al[24] radial artery was cannulated in a large number of children without performing the preliminary Allen's test. They did not see any major complications though. Slogoff et al did a study with 16 adult patients, in whom poor ulnar collateral circulation was assessed with Allen's test. They performed radial artery cannulation in all those patients, but did not have any complications.[25] However, in a small study sample of 16 patients, an incidence of zero does not guarantee that the true incidence of complications will be negligible. In contrast to this, in a study by Mangano and Hickey, they showed a case of hand ischemia requiring amputation later, in a patient in whom the preoperative Allen's test was normal.[26] Patent collateral circulation of the hand can also be documented with pulse oximetry or plethysmography. In a study by Barbeau et al[27] modified Allen's test was compared with pulse oximetry or plethysmography in 1010 patients who were undergoing radial artery cannulation for cardiac catheterization. Pulse oximetry and plethysmography were found to be more sensitive than the Allen's test for detecting inadequate collateral circulation, and it showed only 1.5% of patients were not suitable for radial artery cannulaton, where modified Allen's test excluded 6.3% patients from transradial cannulation.

Alternatively, a long catheter can be inserted percutaneously to obtain a central aortic tracing of arterial BP.[28] This is an uncommon method of radial artery cannulation. In a series of patients undergoing this type of catheterization, no complications were seen.[29] The central arterial tracing is advantageous because in patients with low-flow states or after cardiopulmonary bypass (CPB), its accuracy compared to the radial artery pressure is much more.[30,31] In different studies, the difference between the central and peripheral differences in BP were present, with an incidence ranging from 17% to 40%, although the exact reasons for the difference is not entirely clear.[30,32,33] A decreased arterial elastance is mainly responsible for the lower pressures in the radial artery in comparison to the central arteries post-CPB, as suggested by Kanazawa et al.[34] If the central aortic pressures is palpably high in spite of a low BP in radial arteries, a temporary monitoring of the central pressure has also been advocated by using a needle attached to a pressure tubing placed in the aorta, by the operating surgeon. The femoral artery can also be cannulated alternatively.

During Internal mammary artery dissection, chest wall retractors are used, which can hinder the monitoring of radial arterial pressure in few patients. Perfusion of the affected arm may be decreased during excessive retraction of the chest wall. This problem can be avoided by monitoring the right radial artery, if the left internal mammary artery is to be used for revascularization. A non-invasive BP cuff can also be placed on the right arm that can confirm the accurate radial artery tracing in the time of chest wall retraction.

Radial artery is not to be monitored distal to a site of cutdown of brachial artery, as acute thrombosis or even a residual stenosis of brachial artery may lead to false low readings of radial arterial pressures.[35] There are certain other considerations regarding the choice of monitoring of radial arterial site, including prior hand surgery, selecting the non-dominant hand and surgeon and anaesthesiologist's personal preference.

❖ Techniques of insertion:

➢ Direct cannulation (palpation method) –

Proper technique is important to obtain a good chance of success in cannulation of artery. The wrist is kept dorsiflexed on an arm board, supported by a pack of gauze and to be

Fig – 2: Positioning of hand for Radial artery cannulation immobilized in a supine position. Hyperextension of the wrist causes flattening and decrease in the cross sectional area of the radial artery,[36] so it should be avoided (Figure -2). It may also cause median nerve damage by stretch on the nerve over the wrist, and reduce the likelihood of threading the cannula into the artery. A 3-5 cm non-tapered Teflon catheter of 20 gauge or smaller is to be used for the puncture. There should be a shallow angle between the needle and the skin, and the needle is to be parallel to the artery. When the artery is punctured, the angle between the skin and needle is reduced, and the needle is advanced 1-2 mm more to ensure that the catheter is also within the lumen of artery. Then the outer catheter is threaded off the needle, maintaining the flow of blood out of the needle hub.

- **Doppler assisted technique –**

Doppler probe is used to localize the artery. Acoustic Doppler signal guides the direction of insertion of the percutaneous catheter.[8,9] In small children and infants, it is particularly useful. It may be helpful in adults also when the palpation of artery is difficult, e.g. femoral arterial cannulation in an obese patient. With the more widespread use of color-Doppler and 2D ultrasound devices, the acoustic Doppler assisted method is less commonly used.

- **2D ultrasound-assisted method –**

2D ultrasound assisted methods have complemented the use of Doppler assisted techniques. In a prospective study by Levin et al[37] Ultrasound guided radial artery cannulation was compared to a classic palpation technique. Use of US led to higher success rate of first pass, and the number of subsequent attempts to place the arterial catheter was also less. However, the overall time for catheter placement was not significantly different between the two groups. In a similar study by Shiver et al,[38] patients in the emergency department were randomized to US guided versus palpation technique of radial artery cannulation. Patients of UG group had shorter time, less number of placement attempts and fewer sites required for placement of cannula.

The US guided arterial cannulation technique is easy to learn, if proper training is given. However, the learning curve for the same is significant, and studies reporting on the success rate of US guided arterial cannulation compared to palpation technique must be interpreted accordingly. In a group of pediatric population randomized to US guided or palpation technique, Ganesh et al did not find any significant difference in time and attempts required.[39] However, none of the designated operators had sufficient experience with this technique, with 19 of 20 pediatric subspecialty trainees and fully trained consultant anesthesiologists with experience of fewer than 5 cases.

Figure 3 describes the "Triangulation" technique used for US guided cannulation of arteries. The planes of the needle and the US imaging planes make the two sides of a triangle that meet at the depth of the structure for cannulation. The experienced operator can change the angle between two planes and distance depending on the depth of the structure. The US plane needs to be adjusted further from the needle entry from the skin to the puncture of the vessel to follow the tip of the needle in transverse approach (short axis). Typical US images seen in short-axis cannulation are shown in Figure 4. Often an anatomic variant of a small artery is also present beside the radial artery.

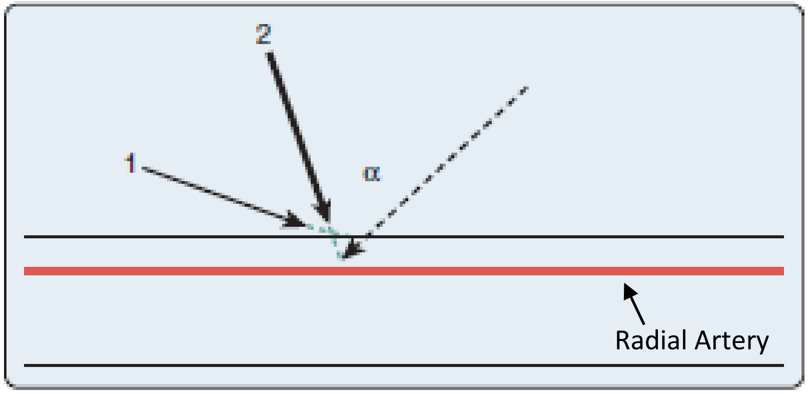

Fig 3: 'Triangulation technique' of US guided radial artery cannulation (1 & 2 – Needle planes; dotted line – Ultrasound plane; α- the angle between the two planes)

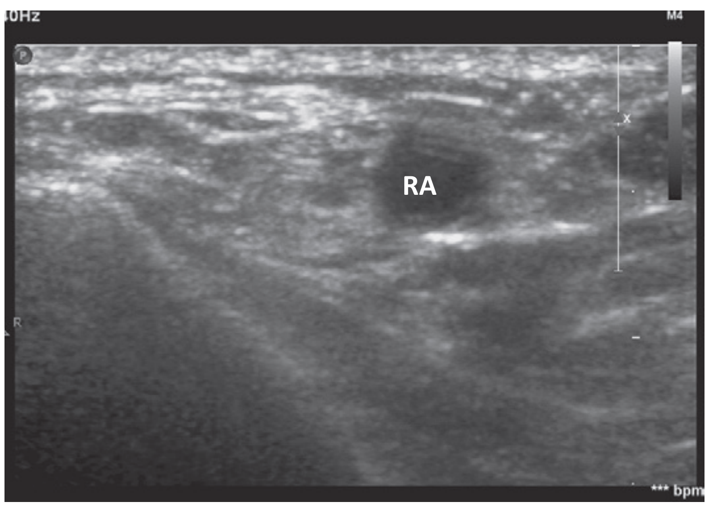

Fig 4: Ultrasound image of Radial artery (RA) in the short axis

The needle tip can be followed more easily during advancement, if a longitudinal or 'in-plane' approach is used. But structures adjacent to the US plane are not visualized simultaneously here. So, most of the practitioners prefer transverse approach. Strict asepsis should be maintained during US guided arterial catheterization, to prevent catheter related infections. A linear array US transducer with high frequency (8-12 MHz) is best for USG placement of arterial catheter, as high-resolution imaging of near field needs higher frequency.

❖ Complications:

➢ Infection

Infection from indwelling catheters is a potential complication common to all invasive monitoring. Infection can be caused by infected skin site, bad aseptic technique of insertion or maintenance, sepsis with catheter seeding, prolonged duration of cannulation etc. Factors like non-disposable transducer domes, contaminated arterial blood gas syringes, dextrose flush solutions, duration of catheter insertion etc. have also been implicated as sources of infection.[40-43] As per literature, barriers with full sterility during placement of arterial catheter did not reduce the risk for infection.[44,45] However, strict asepsis should not be exempted during catheter placement. Guidelines for the prevention of intravascular catheter-related infections have been published by the Hospital Infection Control Practices Advisory Committee and the Centers for Disease Control and Prevention.[46] The concept of removing percutaneous catheters when an infection is suspected has been challenged, and a watchful waiting is suggested until a catheter related blood stream infection is confirmed.[47]

The catheter is to be removed only when infection at the cannulation site or catheter-related bloodstream infection is confirmed. Lymphangitis streaks or cellulitis due to catheter infection require systemic antibiotic therapy.[48]

- **Skin necrosis**

There are reports of volar proximal skin necrosis in patients undergoing radial artery cannulation.[49,50] It has even led to full-thickness skin loss over volar aspect of forearm. It is probably caused by thrombosis of radial artery with proximal advancement of thrombosis to cutaneous branches.

- **Thrombosis and distal ischemia**

Temporary occlusion of the radial artery leading to thrombosis of the artery has been found to be most commonly reported complication of radial cannulation**.**[51] Factors associated with higher incidence of thrombosis include larger catheters, smaller radial artery size and prolonged duration of cannulation.[52-54] The technique of cannulation does not affect the incidence of thrombosis, however it can be reduced with pretreatment with Aspirin.[55,56]

The thrombosis of radial artery may not always be associated with ischemia of the hand. An abnormal Allen's test may not predict hand complications after radial cannulation. Temporary occlusion of radial artery after cannulation is usually benign. However, serious complications of ischemia requiring amputation of digit or extremity have also been reported**.**[57-59] the study by Slogoff et al showed that [25] ischemic complications mostly occurred in patients with embolic phenomena from other sources or who were on high dose of vasopressor support with resultant ischemia.

Thrombosis may manifest several days after removal of the catheter, so, hand is to be examined at regular intervals arterial cannulation. Period of recanalization is generally 13 days, although in this period, the collateral blood flow may not be adequate.[60] Evidence of hand ischemia should be investigated and promptly treated.[61] treatment is traditionally conservative, however fibrinolytic agents, stellate ganglion blockade or surgical intervention can also be considered.

- **Embolization**

If particulate matter or air is flushed forcefully into arterial catheter, it can move proximally and distally inside the artery. Cerebral embolization most commonly arises from axillary catheters but can also arise from brachial and radial artery catheters.[62, 63] Emboli from right arm more likely reaches the cerebral circulation because of the anatomy and aortic arch blood flow direction. Others factors associated with increased risk of embolization include rapidity of injection, volume of the flush solution and proximity of intraluminal tip of catheter to central circulation.[62, 64, 65]

- **Hematoma and neurologic injury**

Formation of hematoma at arterial puncture site, which is particularly common with coagulopathy, can be prevented by applying direct pressure after puncture or correction of the underlying coagulopathy. Posterior puncture in iliac or femoral arteries can cause massive hemorrhage in the retroperitoneal area. Surgical consultation is to be sought in those cases.[66] Nerve damage can occur if the nerve lies with the artery in a fibrous sheath or in a limited tissue compartment[67] or direct injury from needle trauma. However, these are uncommon after radial artery cannulation.

❖ Review of the evidence:

➢ Randomized controlled trials –

Study by Levin et al[37] showed the first attempt success rate with USG to be 62% (21/34) compared to 34% (12/35) using palpation alone in 69 adult patients undergoing elective surgery. In the emergency setting, Shiver et al[38] studied 60 patients requiring arterial catheterization randomized to USG guided or palpation group. They demonstrated a first-pass success rate of 87% in the USG group compared to only 50% in the palpation group.

In a study by Schwemmer et al, [36] 30 infants posted for major neurosurgery had undergone radial artery catheterization. They reported a success rate of 100% in the USG group, compared to 80% in the palpation group. The first-pass success rate was 67% in the USG group and 20% in the palpation group. Small cross sectional area of radial artery may cause difficulty in catheterization. The study showed that by dorsiflexion, the cross sectional area diminishes by around 19%. The higher success rate of USG group may be due to the ability to visualize small vessels by US.

However, there are some randomized controlled trials that have produced equivocal results. USG did not help in faster catheterization of radial artery in 152 pediatric patients by anesthesiologists who were inexperienced in both palpation and USG techniques.[39] Also, the percentage of successful catheterization, total number of attempts and number of catheters used did not differ significantly between the groups. But in many instances where an inexperienced operator failed to cannulate by palpation method, an experienced ultrasound operator could successfully place it with USG. (Ganesh et al)

In 166 patients undergoing preoperative radial cannulation, Tada et al[68,69] did not show an additional benefit of using Doppler US, although in selected cases of hemorrhagic shock, there was some benefit. It is also to be noted that, the method used was marking the proximal and distal points along the anatomical course of the artery, which is likely to be inferior to using real-time USG.

In 112 patients undergoing puncture of femoral artery for interventional investigations, Dudeck et al[70] found that USG should be used to access the femoral artery in patients with leg circumference of 60 cm or more, or in patients with weak arterial pulse. In those patients, procedure time was reduced compared to traditional palpation techniques. Overall attempts were fewer with USG, though statistically insignificant.

- **Case series –**

Techniques of USG have progressed from initial phase of Doppler ultrasound to advanced modalities like B-mode and color duplex US. Nagabhushan et al showed an enhanced catheterization of radial artery and a lesser need of arterial cutdown in patients who were hypotensive or with absent or barely palpable pulses.[71] Study by McLeskey and Mims also showed the usefulness of Doppler assisted cannulation as a salvage technique after failure of traditional techniques. 41 of 45(91%) adult patients were successfully cannulated overcoming problems like arterial spasm, low output states or hematoma.[72] The time and number of punctures required were also markedly less with Doppler assisted technique compared to controls. Morray et al[8] also demonstrated significantly better success rates of radial cannulation with Doppler US compared to cohorts who had palpation techniques(98% versus 91% respectively).

US have been used to aid in the interventional procedures also. USG guided catheterization of arterio-venous fistulae via transbrachial route in hemodialysis patients can be safe and effective. In a series by Lui et al[73] 100% success rate with 96% first-pass rate was achieved with USG. Yeow et al[74] also showed a 96% success rate in patients undergoing USG guided antegrade common femoral artery puncture and access to superficial femoral artery for interventions. This technique reduced the need of standard fluoroscopic guidance. In a series by Marcus et al on lower limb angioplasty, color duplex ultrasound (CDU)-guided catheterization of SFA was safe, effective and faster in patients with scarred groin, failed CFA punctures or obesity.[75] Post procedural hemostasis was also better with USG guided compression of the arterial puncture site.

- **Case reports –**

There are several case reports on the novel uses of USG for arterial cannulation. Kannan et al[76] described a case report of USG guided brachial artery catheterization when traditional attempts failed. Catheterization was possible in a single attempt and arterial pulsations were well visualized despite the presence of extensive interstitial fluid. Similarly, Sandhu NS reported three cases of USG guided catheterization[77,78] of axillary artery through the pectoral muscles and use of US as a rescue technique for failed radial artery cannulation where obstacles like edema, vasospasm or hematoma were overcome by the use USG.

Methodology

❖ **Study Design :**

Prospective, randomized, interventional study

❖ **Subject/participant selection:**

➢ Type – adult patients undergoing cardiac surgery, namely coronary artery bypass grafting (CABG) and valvular heart surgery – replacement or repair of mitral or aortic valve.

➢ Number – We have done a pilot study taking total 120 patients. Patients were randomly divided into 3 groups of 40 each, and were named as per the intervention, viz ultrasound-guided, Doppler-guided or palpation group (n=40).

➢ Eligibility –

- Inclusion criteria –

Adult patients undergoing elective cardiac surgery (CABG or valvular surgery) requiring continuous arterial pressure monitoring.

- Exclusion criteria –
  - Signs of skin infection or a wound near the puncture site
  - Abnormal circulation of the hand
  - Recent arterial puncture <1 month earlier and
  - Patients requiring emergency surgery

- Recruitment – Patients were recruited by the investigators from the operation procedure list. Randomization was done using a computer generated table.

- **Informed consent:** in English and Malayalam

- **Proposed duration of study:** 1 year.

- **Data Collection Procedures:**

After obtaining the approval of Institutional Ethics Committee (IEC), written informed consent from all the patients was taken. Patients were assigned by randomized number generating method into 3 groups, e.g. Ultrasound group, Doppler group and Palpation group.

After explaining the procedure, the patients hand was secured in an arm board with dorsiflexion at wrist joint. Local anesthetic was infiltrated over the cannulation area after cleaning with antiseptic solution.

- Palpation method: Radial artery is palpated and punctured at the site of maximal pulsation. Then a BD (Becton, Dickinson and Company, New Jersey, USA) 20G arterial cannula (Fig 5) is advanced over the needle once flash of blood is seen in the hub of cannula.

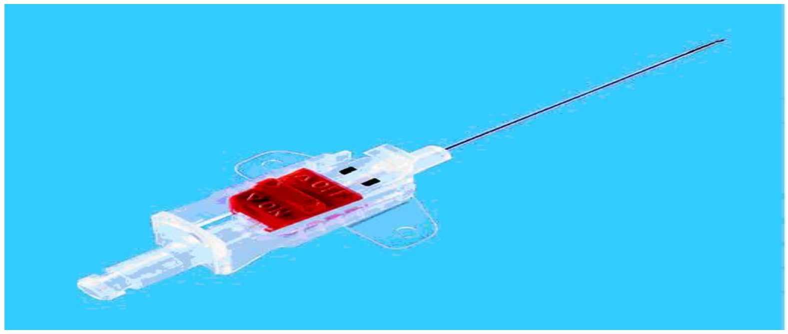

Figure – 5: The 20G BD arterial cannula

- US-guided technique: after preparing the transducer with a sterile cover, the radial artery was identified using US with a linear transducer in short-axis view. Approximately 0.5 cm distal to the probe, a BD 20G arterial cannula was introduced and advanced at 15-30^0 to skin until tip of the needle is seen in contact with the anterior wall of artery. The needle is then advanced as the artery collapses and re-expands or blood appears as flash in the hub. Then the catheter is advanced over the needle.

- Doppler guided technique: The Doppler-assisted technique was performed in the following manner: the radial artery was located where the area of the maximum flow (sound) was found with the Doppler probe. The Doppler probe was held over the artery throughout the cannulation process. The exact position of the artery was identified when increased pitch or loss of Doppler tones indicated that the needle is compressing the artery. The needle was then advanced until blood appeared in the hub or Doppler tones returned to baseline, indicating re-expansion of the artery. Then the catheter was advanced over the needle.

Time to successful arterial cannulation was measured, starting from when either the Doppler or US probe made contact with the patient's skin or palpation started and ending when proper placement of the 20 G cannula were confirmed by appearance of an arterial waveform on the monitor after connecting the catheter to transducer. Attempts were quantified as the number of needle advances through a new skin puncture and the number of times the needle tip is withdrawn from skin and redirected after entering through the same skin puncture. If arterial cannulation was unsuccessful after 10 min, the study was considered to end. The means by which successful arterial cannulation was achieved were recorded. Data were recorded by one of the research team members who was not involved in management of the case. All of the adverse events except blockage of artery were monitored till decannulation. The insertion site and the hand were examined for adverse effects including –

a. Thrombosis (by using ultrasound)
b. Haematoma,
c. Infection (suggested by local swelling and tenderness)
d. Ischaemia distal to the insertion site/ distal discoloration.
e. Blockage of the artery – was monitored till the day following decannulation.

The results of these examinations were added to a summary of complications divided according to the group, which was continuously updated.

❖ **Observations:** following observations were made –

- Time to cannulate –
- Attempts for successful cannulation –

- Was cannulation possible in 10 minutes –

- Vitals before and after cannulation - Heart rate –

  Non-invasive BP (blood pressure) –

  SpO_2 –

- Any complication.

❖ **Data analysis:** All data were entered into an Excel spreadsheet and values were expressed as mean± SD. Categorical data were analyzed using Chi-Square test. Different parametric and non-parametric data were analyzed using standard statistical tests. The non-parametric data were tested by Kruskal-Wallis test, and the parametric data were tested by Single factor ANOVA followed by unpaired t-test assuming unequal variances for post-hoc analysis. A p value <0.05 was considered significant.

Results and Analysis

A total of 120 patients were enrolled, out of which 116 patients were analysed. 2 patients in the palpation group and 1 each in USG and Doppler group were excluded due to inability to record the data due to technical difficulties.

Table 1, Figure 6, 7 shows the demographic characteristics of the three groups. There was no statistically significant difference in terms of mean age, height, weight and BMI among the groups. The male: female sex distribution among the groups also was not significant.

Table 1

Parameter	Palpation	USG	Doppler	p-value
Age (years)	45.8± 6.05	45.5 ±6.72	44.5± 5.07	0.6
Sex (M:F)	25:13	27:12	25:14	0.71
Height (cm)	161.52± 8.35	158.24±5.89	157.64± 7.7	0.055
Weight (kg)	52.87± 4.28	51.89± 4.78	52.94± 5.2	0.56
BMI	20.44±2.98	20.80± 2.41	21.49± 3.16	0.27

The mean age was comparable among the three groups (45.8± 6.05 years in Palpation group, 45.5 ±6.72 years in USG group, and 44.5± 5.07 years in the Doppler group, p=0.6). The mean height and weight were also comparable among the three groups (p=0.055 and 0.56 respectively). The difference in the mean BMI among the three groups was not significant (20.44 in Palpation, 20.80 in USG and 21.49 in Doppler groups, p=0.27). There were 25 males and 13 females in the Palpation group, 27 males and 12 females in the USG group and 25 males and 14 females in the Doppler group (p=0.71).

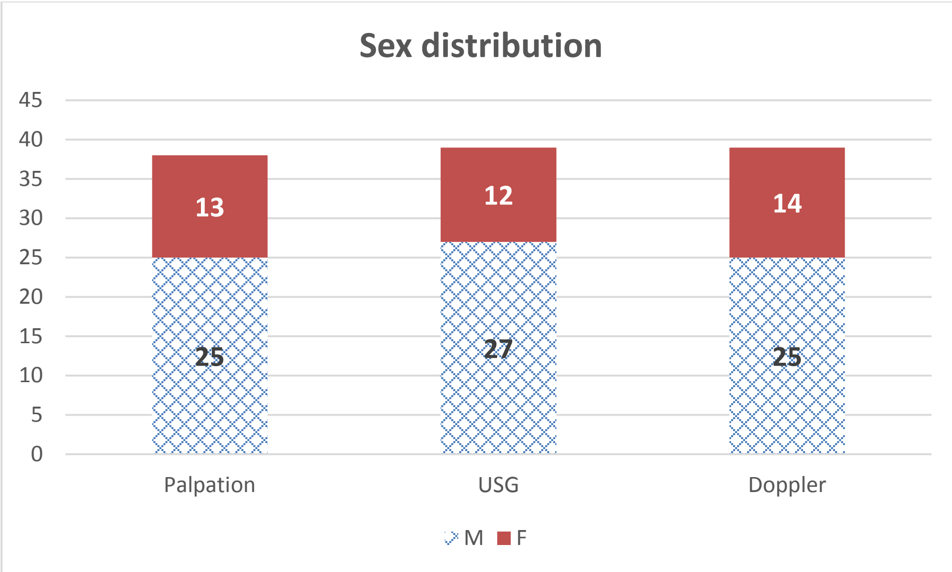

Fig 6 shows the sex distribution (Male: Female) across the three groups.

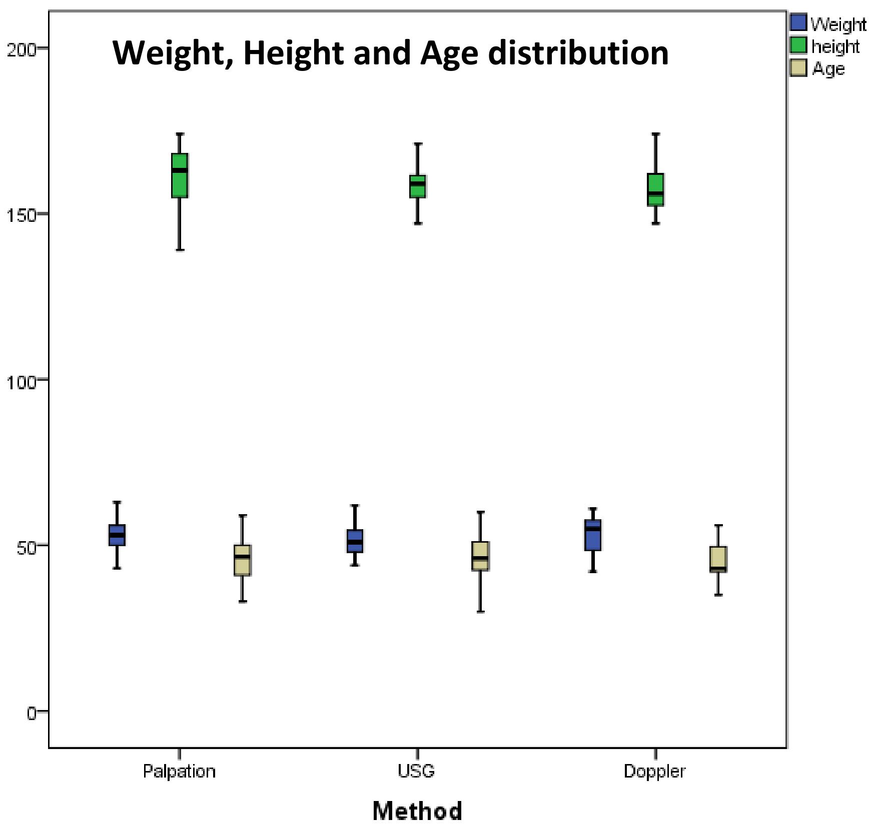

Fig 7 showing the distribution of weight, height and age across the three groups (Boxes represent values between 1st and 3rd quartiles, with median as dark line. Whiskers denote maximum and minimum values)

Table 2, Figure 8, 9 shows the preoperative characteristics of disease conditions of the three groups. There was no significant difference of mean ejection fraction or the distribution of diseases (CAD or valvular heart disease) among the three groups. Premedication was given in all the patients.

Table 2

Parameter	Palpation	USG	Doppler	p-value
Disease/ main pathology (CAD:Valve)	20:18	18:21	21:18	0.52
Ejection fraction	60.51± 4.52	61.08± 3.87	59.36± 3.58	0.16
Premed given	100%	100%	100%	Not significant

The Palpation group had 20 CAD patients, and 18 patients with valvular heart disease. The USG group had 18 and 21 patients having CAD and valvular heart disease, respectively. The Doppler group also had 21 CAD and 18 valvular heart disease patients. This difference in distribution was not statistically significant (p=0.52). The mean Ejection fraction was 60.51 in the palpation group, 61.08 in the USG group and 59.36 in the Doppler group (p=0.16). Premedication was given in 100% of cases in all the three groups, so there is no difference in patients receiving premedication among the groups.

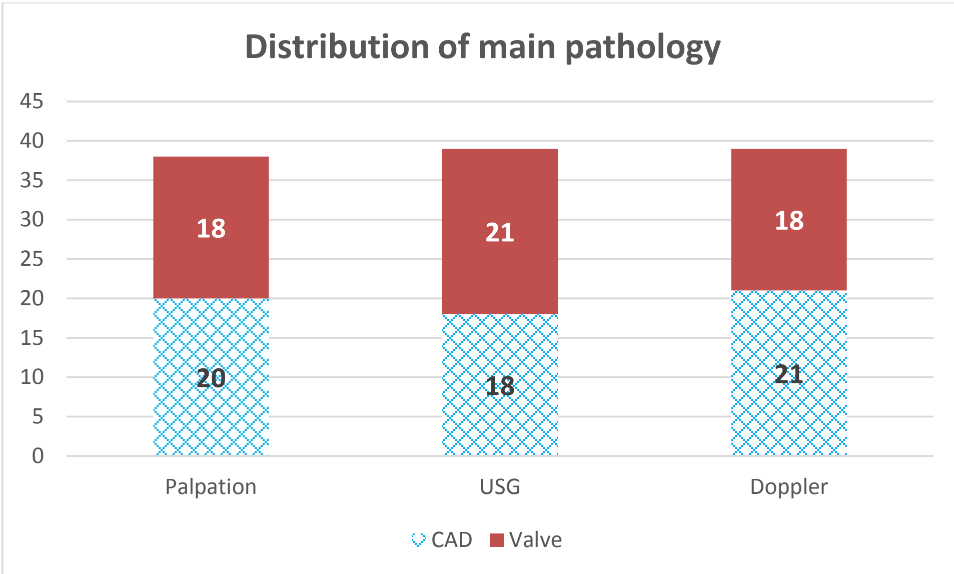

Fig 8 shows the distribution of main pathology (CAD or Valvular heart disease) across the 3 groups.

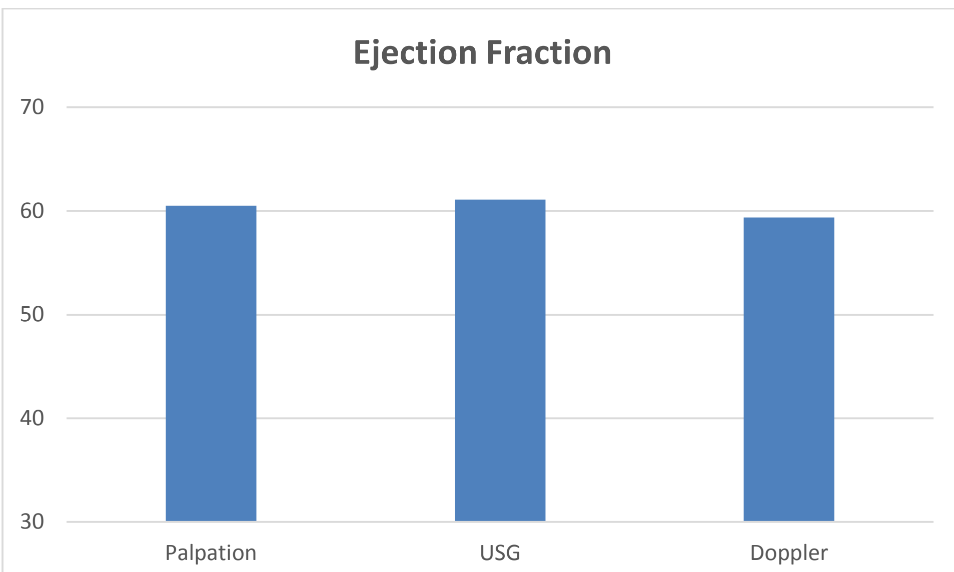

Fig 9 shows the mean ejection fraction among the 3 groups.

Table 3, Figure 10,11,12,13 compares the rate of success and effectiveness of the three methods for radial artery cannulation. The time to cannulate and number of attempts required for successful cannulation was significantly higher in the Doppler assisted group (p=0.01 and 0.001, respectively). However, there was no significant difference between the palpation and USG guided groups in terms of time to cannulate, number of attempts required and rate of successful cannulation. Cannulation was possible in almost all cases of Palpation and USG guided groups (95% and 92%, respectively), but it was possible only in 66% of people where Doppler method was used. This is also statistically significant ($p < 0.05$). The First-pass success rate was found to be significantly high in Palpation group (57.9%) compared to the other two groups (p=0.0005).

Table 3

Parameter	Palpation	USG	Doppler	p-value
Time to cannulate (sec)	74.21± 9.26	75.89± 7.35	212.46± 10.4*	**0.01**
No of attempts	1.3± 0.47	2± 0.99	3.87± 1.22*	**0.001**
Cannulation possible	95%	92%	66%*	**0.0004**
First pass success rate	57.9%*	41%	7.7%	**0.0005**

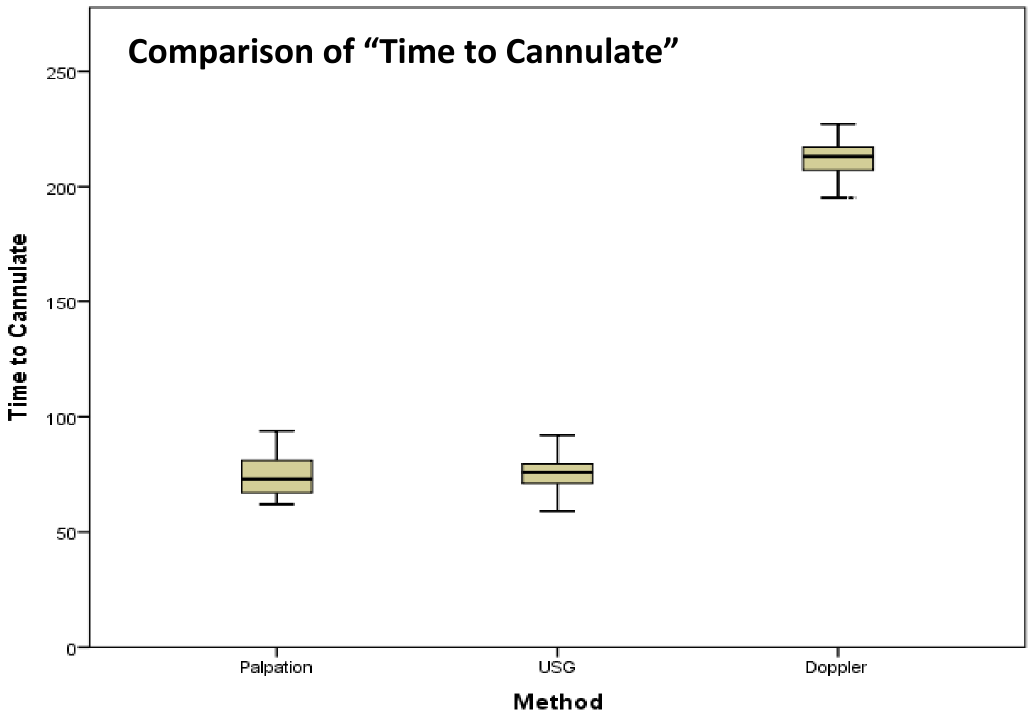

Fig 10 shows the comparison of mean 'Time to cannulation' (measured in seconds) across the 3 groups. (Boxes represent values between 1st and 3rd quartiles, with median as dark line. Whiskers denote maximum and minimum values)

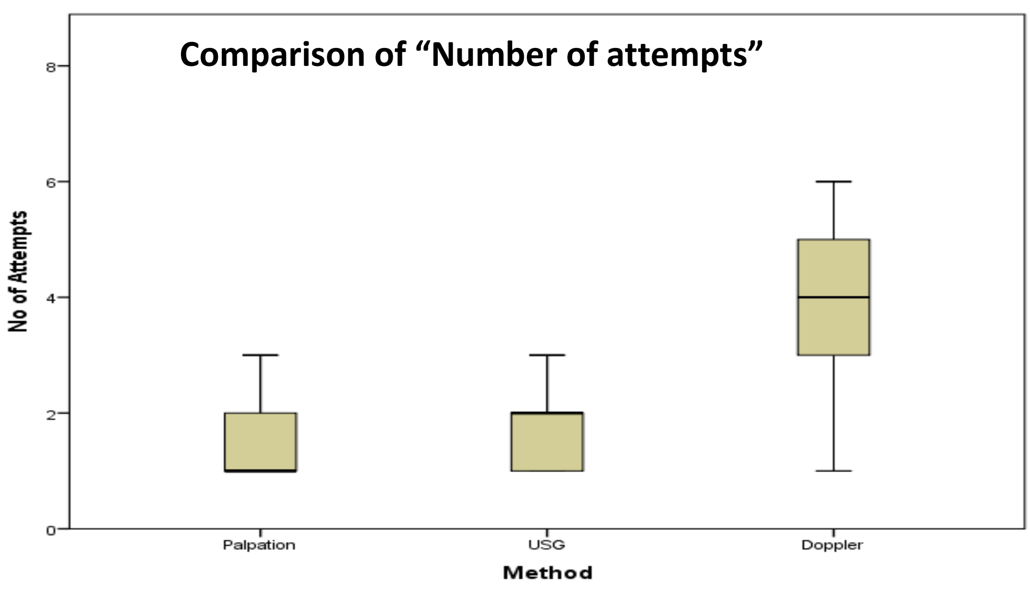

Fig 11 shows the comparison of mean 'Number of attempts' across the 3 groups. (Boxes represent values between 1st and 3rd quartiles, with median as dark line. Whiskers denote maximum and minimum values)

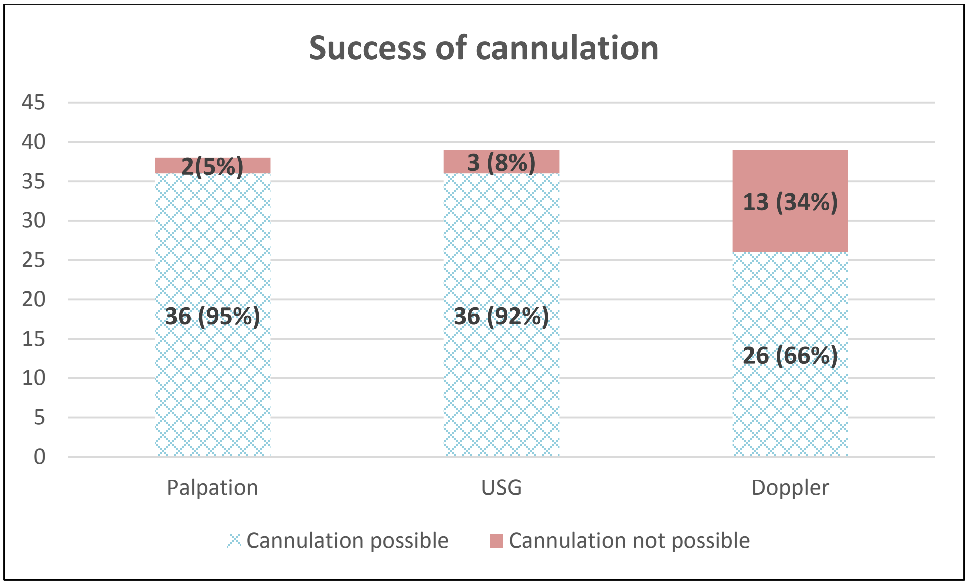

Fig 12 compares the ‘Success rate of cannulation’ across the 3 groups.

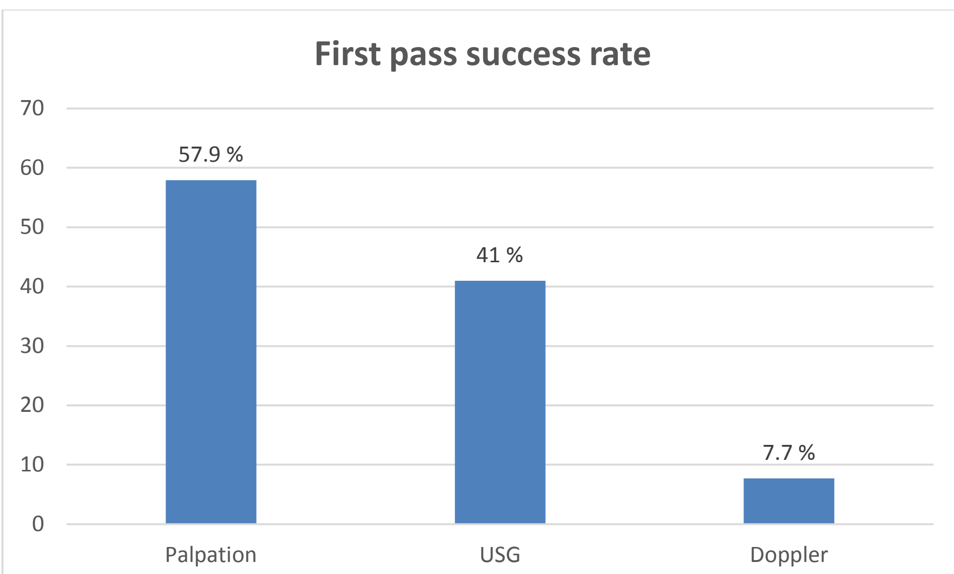

Fig 13 shows the comparison of the ‘First pass success rate’ among the 3 groups.

Table 4, Figure 14, 15 shows the comparison of vital parameters (heart rate, NIBP and SpO2) among three groups. There was no significant difference among the groups either before or after cannulation.

Table 4

Parameter	Palpation	USG	Doppler	p-value
Heart Rate BL	71.78± 3.99	72.02± 2.43	72.45± 3.96	0.71
NIBP (Systolic) BL	150.39± 7.18	151.07± 4.93	153.18± 5.11	0.09
NIBP (Diastolic) BL	92.82± 4.26	91.96± 2.49	93.71± 3.66	0.1
SpO_2 BL	99.81± 0.45	99.89± 0.30	99.87± 0.40	0.68
Heart Rate AC	75.63± 5.49	75.12± 3.39	77.02± 2.99	0.11
NIBP (Systolic) AC	157.22± 4.35	158.47± 2.57	159.51± 5.26	0.06
NIBP (Diastolic) AC	96.86± 3.14	96.8± 4.77	98.75± 3.49	0.053
SpO_2 AC	99.84± 0.36	99.87± 0.40	99.79± 0.46	0.79

(BL – Baseline/ before cannulation; AC – after cannulation)

The baseline heart rate was comparable among the three groups (p=0.71), the baseline non-invasive BP was also comparable among the three groups (p=0.09 and 0.1, respectively for systolic NIBP and diastolic NIBP).

The Heart rate, systolic and diastolic BP after cannulation also did not differ significantly among three groups (p=0.11, 0.06 and 0.053, respectively).

The mean SpO2 was comparable among the three groups, both before and after cannulation (p= 0.68 and 0.79, respectively).

Table 5, Figure 16 describes the complication rates of different methods, post arterial puncture. There were very few adverse effects associated with the methods.

Table 5

Complications	Palpation	USG	Doppler	p-value
Thrombosis			1	Not significant
Distal discoloration	1			
Hematoma		1	1	
Cannulation site infection		1		
Blockage of artery				

In Palpation group, 1 patient had distal discoloration. In the USG group, 1 patient had local hematoma. 1 patient had cannulation site infection. In the Doppler group, 1 patient had thrombosis. 1 had hematoma in the Doppler group. Blockage of the artery was not seen in any of the patients. Overall the incidence of complications {1 out of 38 patients (0.026%) in Palpation group, 2 out of 39 patients (0.05%) in USG group and 2 out of 39 patients (0.05%) in Doppler group} was very less, and p value was not statistically significant.

Comparison of “vital parameters before cannulation”

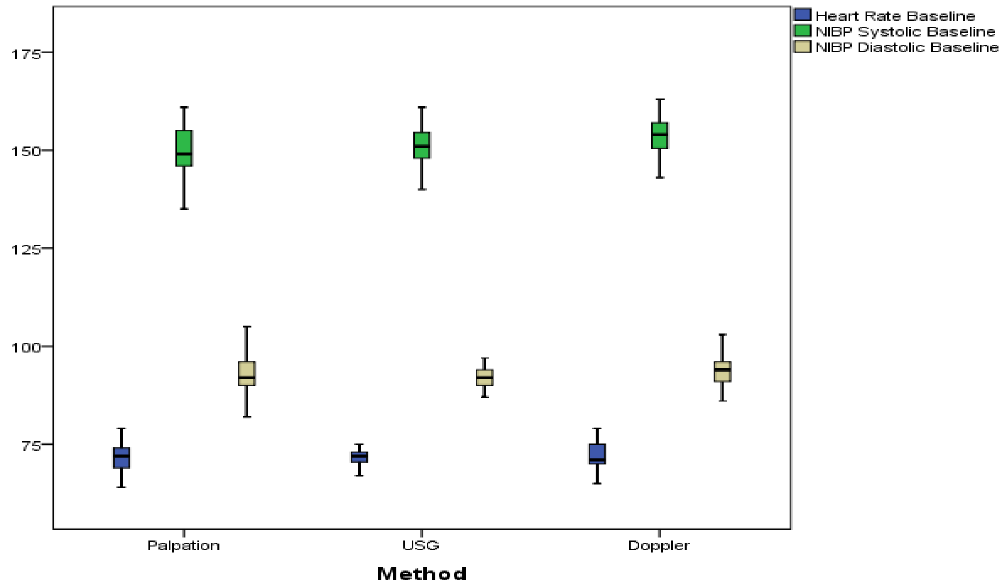

Fig 14 compares the ‘before cannulation/ baseline’ vital parameters (Heart rate, Systolic NIBP, Diastolic NIBP) among the 3 groups. (Boxes represent values between 1st and 3rd quartiles, with median as dark line. Whiskers denote maximum and minimum values)

Comparison of “vital parameters after cannulation”

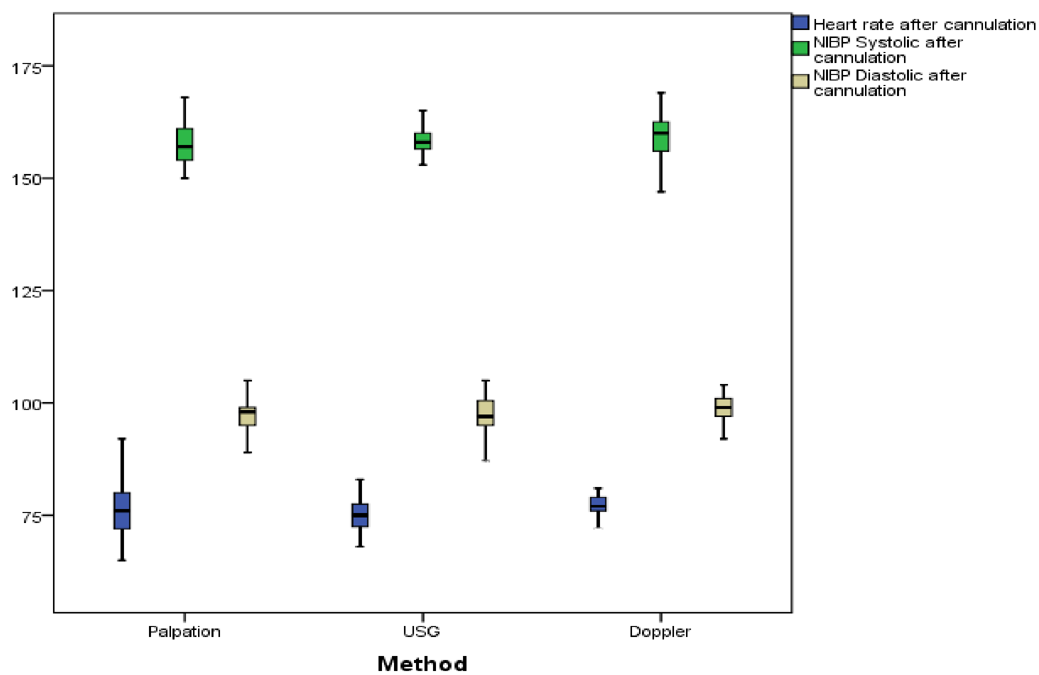

Fig 15 compares the vital parameters (Heart rate, Systolic NIBP, Diastolic NIBP) ‘after cannulation’ among the 3 groups. (Boxes represent values between 1st and 3rd quartiles, with median as dark line. Whiskers denote maximum and minimum values)

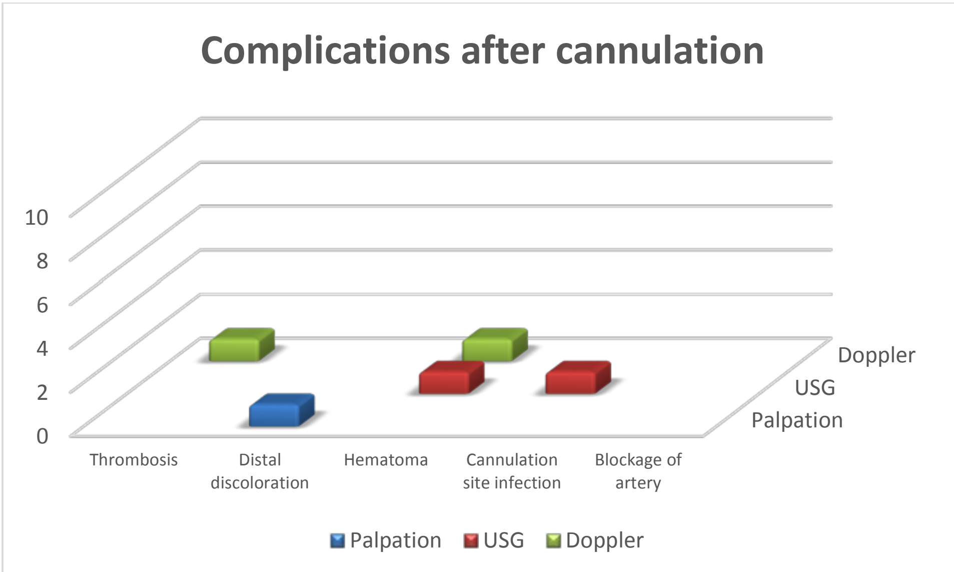

Fig 16 shows the comparison of various complications seen after cannulation across the 3 groups.

Discussion

Arterial cannulation and the continuous transduction of arterial pressure still remains the accepted reference for monitoring of arterial blood pressure. Although the risk involved, cost and the need for technical expertise required for the placement and management of arterial cannula may be quite high, its usefulness in providing the important and timely information clearly outweighs the risks in many cases.

The potential for the analysis of arterial pressure waveform to produce valuable diagnostic information probably remains one of the most underemphasized utilities of direct arterial pressure monitoring. This idea was proposed long time back by Eather et al, who advocated the monitoring of arterial pressure and pulse contours in patients under anaesthesia.[79] Few aspects of arterial waveform are commonly used, such as the recognition of dicrotic notch to guide the proper timing of IABP balloon inflation, but other uses e.g. predicting the preload reserve by the excessive variation of arterial blood pressure have received significant attention recently.[80]

This prospective, randomized study demonstrated the superiority of US-guided and palpation method over Doppler assisted methods for cannulating the radial artery in adult cardiac surgical patients. There are studies about the superiority of US assisted method over palpation for vascular cannulation**,** [36,81,82] but literature about this in the adult cardiac patients is few.

Previous studies who investigated the utility of US guided radial artery cannulation came up with conflicting evidences. Schwemmer et al[36] reported a 100% success rate in the

USG group, compared to 80% in the palpation group. They also noted that the first-pass success rate was 67% in the USG group and 20% in the palpation group.

On the contrary, Ganesh et al did not find USG to be helpful in faster catheterization of radial artery in 152 pediatric patients by anesthesiologists who were inexperienced in both palpation and USG techniques.[39] They have also shown that the percentage of successful catheterization, total number of attempts and number of catheters used did not differ significantly between the groups.

The conflict in results can be attributed to different age group of the patients, and the different experience of the operators in using the USG. In our study, we did not find any significant difference in the age distribution of the patients, and all the cannula placements were done by a single operator, thereby eliminating an inter-operator bias.

Study by Ueda et al[83] included 104 pediatric patients, who were divided randomly into USG guided or Doppler guided methods for radial artery cannulation. They found out that USG guided group had significantly higher first-pass success rate (33%) compared to the Doppler guided group (15%). Also their % of successful cannulation within 10 minutes was more with USG group (65%) in comparison to the Doppler group (46%). These findings were similar to our study; we also found that the first pass success rate was 41% in the USG group and 7.7% in the Doppler group, the difference being statistically significant. Our rate of successful cannulation within 10 minutes was also higher in USG group (92%) compared to the Doppler group (66%), the difference being statistically significant ($p=0.0004$).

Our study differed from the one by Ueda et al by quite a few aspects, for example, we had only the adult cardiac surgical patients, in whom the evaluated parameters of radial artery cannulation (e.g. time to cannulate, number of attempts etc.) may be altered by their disease process itself. Different diseases may alter the pulse characteristics and radial arterial inner structure, which may pose a challenge for a new method like US or Doppler to succeed. Moreover, we compared these 2 methods with the traditional palpation or the blind method, because that is the most commonly used method in our center, and is also a widely accepted method in several places where non-availability of an anesthesiologist expert in US or Doppler may limit their use. All these cannulations were done by a single operator, to eliminate any interpersonal bias.

Our findings did not corroborate with that of Levin et al,[37] who compared USG method versus palpation in 69 adult patients, and found that the time to cannulate was significantly higher in USG group (26.1s) vs palpation (17.3s). Also their mean time to successfully cannulate in the first attempt was higher in USG group. However, the mean no of attempts per patient was significantly lower in the USG group (1.6±1.0) than the palpation group (3.1±2.4), p=0.003. This discrepancy may be due to the fact that many of the performing anaesthetists were new to the use of USG for arterial cannula placement, though they had previous experience of cannulating the central vein with USG. The patient population in this study was also from a mix of cardiac and noncardiac surgeries, which may cause a bias in the chance of success, though the distribution was not statistically significant here.

Similar findings to the previous study were noted in the study by Shiver et al,[38] where 60 adult patients attending the emergency department had undergone radial artery cannulation by palpation or USG guided method. It was done by operators who had experience in USG guided CVC placement, but not arterial placement. They showed that the first-pass success rate in the USG group was 87%, and in the palpation group was 50%, which was statistically significant (p=0.005).

Our first-pass success rate with USG was lower than that shown in a study by Jonathan R et al[84] (80%), where 50 patients underwent USG guided radial artery cannulation by a single interventional cardiologist with minimal prior experience with USG. The mean time to cannulate the artery was also lower in their study (61 sec) in comparison to our study (75.8 sec). However, the patients included in their study did not have any cardiac disease, which may have influenced the difference in outcome.

In a meta-analysis conducted by Gu et al[85] to compare the efficacy of USG with other methods of radial cannulation, seven randomized controlled trials were included – out of which, six had taken palpation group as control, and one has taken Doppler as control. The primary outcome was rate of first-attempt success, and USG guided method was associated with an increased first-attempt success than controls. (p=0.04) The mean attempts to success and mean time to success were also significantly reduced with USG. This finding is partly similar to our study, as we found USG to be superior to Doppler, but not to Palpation method. In almost all of the RCTs, the performing anaesthesiologists had experience of USG guided central venous catheterization and minimal USG guided arterial catheterization, as in our study. However, they commented that the learning curve for USG guided radial artery catheterization can affect the first-attempt success rate and other clinical end-points, and inexperienced operators can overcome this difficulty by continuous training.

Morray JP et al[8] conducted 310 consecutive radial cannulations by Doppler assisted or palpation method, on infants and children of age 1 day to 18 years, who were undergoing general anesthesia for cardiac surgery. They showed that the percentage of successful attempts were significantly higher with the use of Doppler than palpation in patients weighing less than 6 kg (p=0.01), but in patients with weight more than 6 kg, there was no statistically significant improvement in successful cannulation percentage between the two groups. Also, the mean cannulation time was significantly higher in the less than 6 kg group (7.6± 8.1 min) in comparison to the patients weighing more than 6 kg (6.5± 6.7 min). Our study also found out that in adult patients, mean time to cannulate was significantly higher in Doppler assisted group than other two groups. The percentage of successful cannulation was also lower (66%) in comparison to the other two groups (92 and 95%).

With the use of Doppler, Fukutome T et al[9] could locate the radial artery in 25 of 28 children, aged from 1 to 2 years and scheduled for cardiovascular surgery. They could cannulate the artery successfully in 24 of these 25 children. However, this should be kept in mind that in only 8 patients, they could locate the artery percutaneously; in all other cases, they had to make a 2-3 mm incision over the most prominent pulsation area, thus locating the artery by invasive method.

The negligible number of complications in our study (2 in USG and Doppler, 1 in palpation group) may be due to the less number of cases taken. The study by Seto et al[86] comparing 1004 patients on fluoroscopy vs USG for vascular access found that USG decreases the complication rate significantly (3.4% in fluoroscopy group, 1.4% in USG group, p=0.04).

In another study of 104 patients comparing US and Doppler methods,[83] 2 patients of Doppler group developed hematoma on post-operative day 1, both cases resolved without treatment. No ischemic complications were noted on post-operative days 1 and 3. This finding is similar to our study, where we had 2 complications in USG and Doppler group each, and 1 complication in the Palpation group.

A review by Scheer et al[51] showed the most common complications to be temporary radial artery occlusion (19.7%) and hematoma, followed by local site infection (0.7%) and hemorrhage, or very rarely pseudoaneurysm formation. However we found only 2 cases of hematoma formation, one case of local site infection (0.008%) and one case of thrombosis. We did not encounter any blockade of radial artery afterwards.

Inadequate experience of placing catheters as evidenced by increased number of attempts and many places of hematoma formation – may also influence the complication rate.[87,88,89]

Thrombosis or temporary occlusion of the radial artery can be associated with detection of inadequate circulation of hand in pre-cannulation Allen's test. A prospective study of 100 patients by Cederholm et al[90] found that out of 7 patients with poor flow detected by pre-cannulation Allen's test, 5 had signs of thrombosis (71%). Again, 9 out of 13 patients who had developed hematoma after cannulation, subsequently developed signs of thrombosis. However this finding is quite different from our study, where we have found 2 cases of hematoma and 1 case of thrombosis, though we excluded all patients with compromised collateral flow detected in the precannulation Allen's test. Another point to remember is, this study followed up patients for signs of thrombosis for a few weeks, and eventually thrombosis was seen up to 14 days after cannulation. We followed up patients for one day after cannulation, which may be the cause of our missing out on some incidences of thrombosis occurring later.

Further studies on this subject should focus on the various shortcomings of the existing studies. There is a need for some more consistency regarding the frequency of the ultrasound probe used and the experience level of operators. Till date, a great variability exists in the available literature. Moreover, future studies should pay attention to secondary clinical endpoints (other than first attempt success rate) such as patient pain, patient and physician satisfaction etc. Finally, almost none of the included studies have specially evaluated the use of ultrasound guidance in cases of difficult radial artery catheterization. Further studies may focus on the efficacy of ultrasound guidance in difficult radial artery catheterization situations, including patients with severe hypotension and morbid obesity.

Conclusion

1. Palpation and USG are superior methods than Doppler for radial artery cannulation in adult cardiac surgical patients, having significantly higher rates of successful cannulation. Doppler method was also shown to be inferior, by requiring significantly higher number of attempts, and longer time for cannulation than Palpation or USG methods.

2. Though the Palpation group had statistically higher first pass success rate than USG or Doppler group, this can be attributed to the relative inexperience of the performer with USG or Doppler.

3. There was no statistically significant difference between Palpation and USG groups, in terms of number of attempts required for cannulation, % of successful cannulation or time taken to successfully cannulate the radial artery. So we can conclude that Palpation and USG-guided methods are equally good choices for radial arterial cannulation, and USG offers no added advantage over the Palpation method.

4. The complication rates were very low for all the methods, so the newer methods (USG and Doppler) did not offer any advantage regarding reduction of complications following arterial cannulation.

Limitation

Ours being a single center pilot study, the sample size was kept small (120 patients), as no reference for calculating the sample size by minimizing the alpha error and maximizing the power was available. Probably a multicenter study with a greater sample size can better establish the superiority or inferiority of one method over another.

The learning curve for newer techniques like USG and Doppler holds true, as all the cannulations were done by an anesthesiologist with relatively less experience in newer modalities like USG or Doppler, and may even be responsible for the relative superiority of the traditional palpation method over the newer techniques, in terms of better first-pass success rate.

Emergency patients or patients with acute hemodynamic disturbances were excluded from our study. If those cases were included, the effectiveness of the USG or Doppler could have been more widely evaluated.

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Annexure

Informed Consent Form (English)

Title of study: COMPARISON OF THREE DIFFERENT METHODS OF RADIAL ARTERY CANNULATION: A PROSPECTIVE RANDOMIZED STUDY

Study numbers: We request you to participate in the study where we are planning to evaluate the efficacy and success rate of US and Doppler guided radial artery cannulation over palpation method of radial artery cannulation in 120 patients undergoing cardiac surgery.

What are the different techniques of measurement of BP ?

BP can be measured by invasive or non-invasive method. Invasive method is by inserting an arterial cannula and connecting transducer to it. Non-invasive method is by auscultatory method or oscillometric method. Auscultatory method is more commonly applied method, using a stethoscope and a sphygmomanometer.

Why is invasive BP monitoring needed?

Arterial cannulation for major surgery is essential for the continuous monitoring of arterial pressure and arterial blood sampling. Cardiac surgical patients have significant hemodynamic alterations throughout perioperative period. So continuous beat-to-beat monitoring of arterial pressure is essential for those patients undergoing cardiac surgery.

Moreover, cardiac surgery patients require frequent blood sampling for performing arterial blood gas analysis, which gives an idea about gas exchange, electrolytes and acid-base status of the body. For these reasons, arterial cannulation is routinely performed for all cardiac surgical patients in our institute.

Why is radial artery cannulated?

Radial artery is easily palpable, easy to cannulate, readily accessible during surgery, bears an almost constant location near the wrist, does not have any accompanying major vein and have adequate collateral circulation that is easy to check. That's why radial artery is cannulated routinely.

How the cannula is put?

After explaining the procedure, the patients hand will be secured in an arm board in dorsiflexed position. Local anesthetic will be infiltrated over the cannulation area after cleaning with antiseptic solution.

Palpation method: artery is palpated and punctured at the site of maximal pulsation. Then catheter is advanced over the needle once flash of blood is seen in the hub of cannula.

US-guided technique: after preparing the transducer with a sterile cover, the radial artery will be identified using US with a linear transducer in short-axis view. Approximately 0.5 cm distal to the probe, a 20G BD cannula will be introduced and advanced at $15\text{-}30^0$ to skin until tip of the needle is seen in contact with the anterior wall of artery. The needle is then advanced as the artery collapses and re-expands or blood appears as flash in the hub. Then the catheter is advanced over the needle.

Doppler guided technique: The Doppler-assisted technique will be performed in the following manner: the radial artery will be located when the area of the maximum flow (sound) was found with the Doppler probe. The Doppler probe will be held over the artery throughout the cannulation process. The exact position of the artery will be identified when increased pitch or loss of Doppler tones indicated that the needle is compressing the artery. The needle will then be advanced until Doppler tones returned to baseline, indicating re-expansion of the artery, or blood appeared in the hub. Then the catheter is advanced over the needle.

What are the risks and side-effects?

Temporary arterial occlusion is the most common complication of radial artery cannulation and is usually benign. But serious ischemic complications requiring amputation of the digit or extremity have been reported (incidence less than 0.002%), volar proximal skin necrosis, hematoma (14%) and tissue compartment syndrome and late vascular complication like pseudoaneurysm formation (0.09%) have also been reported in a few cases.

Why are we doing the study?

We are doing this study to find out the effectiveness of newer imaging modalities like US and Doppler over palpation method in cardiac patients, in whom there is wide variation of heart rate and pulse volume, making it difficult to cannulate by blind palpation method.

Can you withdraw from this study after it starts?

Your participation in this study is entirely voluntary and you are also free to decide to withdraw permission to participate in this study. If you do so, this will not affect your usual treatment at this hospital in any way.

What will happen if you develop any study related injury?

We do not expect any injury to happen to you but if you do develop any side effects or problems due to the study, these will be treated at no cost to you. We are unable to provide any monetary compensation, however.

Will you have to pay for the study?

No.

Will your personal details be kept confidential?

The result of this study will be published in a medical journal but you will not be identified by name in any publication or presentation of results. However the medical notes will be reviewed by people associated with the study, without your permission, should you decide to participate in this study.

If you have any further questions, please ask:

Dr. Suddhadeb Roy, senior resident, Dept of anaesthesia (Tel: 9645206961) or mail me: suddha@sctimst.ac.in

Dr. Prasanta Kumar Dash, professor, Dept of anaesthesia (Tel: 09349336584)

Dr.Rupa Sreedhar, professor, Dept of anaesthesia (Tel: 9446314043)

DECLARATION

I, ______________________________________ (Please tick boxes) •Participant's name: Date of Birth / Age (in years)

Declare that I have read the above information provided to me regarding the study: COMPARISON OF THREE DIFFERENT METHODS OF RADIAL ARTERY CANNULATION: A PROSPECTIVE RANDOMIZED STUDY

And have clarified any doubts that I had. [ ]

• I also understand that my participation in this study is entirely voluntary and that I am free to withdraw permission to continue to participate at any time without affecting my usual treatment or my legal rights [ ]

• I understand that the study staff and institutional ethics committee members will not need my permission to look at my health records even if I withdraw from the trial. I agree to this access [ ]

• I understand that my identity will not be revealed in any information released to third parties or published [ ]

• I voluntarily agree to take part in this study [ ]

• I received a copy of this signed consent form [ ]

Name:

Signature:

Date:

Name of witness:

Relation to participant:

Date:

(Person Obtaining Consent)

I attest that the requirements for informed consent for the medical research project described in this form have been satisfied. I have discussed the research project with the participant and explained to him or her in nontechnical terms all of the information contained in this informed consent form, including any risks and adverse reactions that may reasonably be expected to occur. I further certify that I encouraged the participant to ask questions and that all questions asked were answered.

__________________________________ ____________________

Name and Signature of Person Obtaining Consent

Informed Consent Form (Malayalam)

<u>സമ്മത പത്രം</u>

പഠന ശീർഷകം:

റേഡിയൽ ശുദ്ധരക്ത ധമനിയിലെ കുഴൽ കടത്തലിന്റെ മൂന്ന് വ്യത്യസ്ത രീതികളുടെ താരതമ്യം. ഒരു ദീർഘ വീക്ഷണത്തോടെയുള്ള ക്രമരഹിത പഠനം.

പഠനവ്യാപ്തി:

ഹൃദയ ശസ്ത്രക്രിയക്കു വിധേയരാകുന്ന 120 രോഗികളിൽ സ്പർശനത്തിലൂടെ നിർണയിച്ച് റേഡിയൽ ശുദ്ധരക്ത ധമനിയിൽ കുഴൽ കടത്തുന്നതിന് പകരം അൾട്രാസൗണ്ടിന്റെയും ഡോപ്ലറിന്റെയും മാർഗനിർദേശമനുസരിച്ച് റേഡിയൽ ശുദ്ധരക്ത ധമനിയിൽ കുഴൽ കടത്തുന്നതിന്റെ ഉപയോഗക്ഷമതയും വിജയശതമാനവും വിലയിരുത്താൻ ഉദ്ദേശിക്കുന്ന പഠനത്തിൽ പങ്കെടുക്കുവാൻ ഞങ്ങൾ താങ്കളോട് അഭ്യർത്ഥിക്കുന്നു.

ഉള്ളിലൂടെയുള്ള രക്ത സമ്മർദ്ദ നിരീക്ഷണത്തിന്റെ ആവശ്യമെന്ത് ?

ശുദ്ധരക്തധമനിയിലെ സമ്മർദ്ദത്തിന്റെയും രക്ത മാതൃകകളുടെയും നിരന്തരമായ നിരീക്ഷണത്തിന് ശുദ്ധരക്ത ധമനിയിൽ കുഴൽ കടത്തുന്നത് ഗുരുതരമായ ശസ്ത്രക്രിയകൾക്ക് അത്യന്താപേക്ഷിതമാണ്. ശസ്ത്രക്രിയാഘട്ടത്തിലുടനീളം രക്ത ചംക്രമണത്തിലുള്ള നിർണായകമായ വ്യതിയാനങ്ങൾ ഹൃദയശസ്ത്രക്രിയാ രോഗികളിലുണ്ടാകും. ആകയാൽ തുടർച്ചയായി ഹൃദയമിടിപ്പിന്റെയും രക്തധമനിയിലെ സമ്മർദ്ദത്തിന്റെയും നിരീക്ഷണം ഹൃദയ ശസ്ത്രക്രിയക്കും വിധേയരാകുന്ന രോഗികൾക്ക് അത്യന്താപേക്ഷിതമാണ്.

മാത്രമല്ല ഹൃദയ ശസ്ത്രക്രിയാ രോഗികൾക്ക് ശുദ്ധരക്തത്തിലെ വാതക വിനിമയത്തിന്റെ വിശകലനത്തിനും വൈദ്യുത ചാലകങ്ങളുടെയും ശരീരത്തിലെ അമ്ലാധിഷ്ഠിത നിലവാരത്തിന്റെയും പഠനത്തിന് അടിക്കടി രക്തമാതൃക ആവശ്യമാണ്. ഇക്കാരണങ്ങളാൽ ശുദ്ധരക്ത ധമനിയിലെ കുഴൽ കടത്തൽ എല്ലാ ഹൃദയശസ്ത്രക്രിയക്കു വിധേയരാകുന്ന രോഗികൾക്കും നമ്മുടെ സ്ഥാപനത്തിൽ നടത്തി വരുന്നു.

എന്തുകൊണ്ട് റേഡിയൽ ശുദ്ധരക്തധമനിയിൽ കുഴൽ കടത്തുന്നു?

റേഡിയൽ ശുദ്ധരക്തധമനി എളുപ്പത്തിൽ സ്പർശിച്ചറിയാവുന്നതും കുഴൽ കടത്തുന്നതിന് എളുപ്പമുള്ളതും കുഴൽ കടത്തുന്നതിന് എളുപ്പമുള്ളതും ശസ്ത്രക്രിയക്കിടയിൽ സുഗമമായി സമീപിക്കാവുന്നതും ഏകദേശം സ്ഥിരമായി മണി ബന്ധത്തിനടുത്ത് നിലകൊള്ളുന്നതും എളുപ്പത്തിൽ പരിശോധിക്കാൻ പര്യാപ്തമായ രക്ത ചംക്രമണമുള്ളതും പ്രധാനപ്പെട്ട അശുദ്ധരക്തക്കുഴലിന്റെ സാമീപ്യം ഇല്ലാത്തതുമാണ്. അതുകൊണ്ടാണ് സാധാരണയായി റേഡിയൽ ശുദ്ധരക്ത ധമനിയിൽ കുഴൽ കടത്തുന്നത്.

എങ്ങനെയാണ് കുഴൽ കടത്തുന്നത്.?

നടപടിക്രമങ്ങൾ വിശദീകരിച്ച ശേഷം രോഗിയുടെ കൈ കൈപ്പലകമേൽ മലർത്തി ഭദ്രമാക്കി വയ്ക്കുന്നു. കുഴൽ കടത്തുന്ന സ്ഥലം അണുവിമുക്തമാക്കിയ ശേഷം പ്രാദേശികമായി മയക്കുന്നതിനുള്ള മരുന്ന് കുത്തി വയ്ക്കുന്നു.

സ്പർശന രീതി:

ശുദ്ധരക്തകുഴൽ സ്പർശിച്ചറിഞ്ഞ് പരമാവധി സ്പന്ദനമുള്ള സ്ഥലത്ത് തുളക്കുന്നു. എന്നിട്ട് കുഴലിൽ രക്തം പ്രത്യക്ഷപ്പെടുമ്പോൾ കുഴൽ മുന്നോട്ട് നീക്കുന്നു. അൾട്രാസൗണ്ട് നിർദ്ദേശിത രീതി ട്രാൻസ്ഡ്യൂസർ അണുവിമുക്തമായ ആവരണത്തിൽ ആക്കിയ ശേഷം റേഡിയൽ ശുദ്ധരക്തധമനി നീണ്ട് ട്രാൻസ്ഡ്യൂസറിന്റെ സഹായത്താൽ അൾട്രാസൗണ്ട് ഉപയോഗിച്ച് കണ്ടെത്തുന്നു. ഏകദേശം 0.5 സെന്റിമീറ്റർ പരിശോധനാ ഉപകരണത്തിൽ നിന്നും മാറി 15-30 ചരിവിൽ ഒരു 20 ഗ്രാം കത്തീറ്റർ ശുദ്ധരക്തധമനിയുടെ പുറം ഭിത്തിയിൽ

സൂചി സ്പർശിക്കുന്നതുവരെ കടത്തുന്നു. ശുദ്ധരക്തധമനി മടങ്ങുകയും പുനർവികസികക്ുകയും ചെയ്യുകയോ സൂചിയുടെ അഗ്രത്തിൽ രക്തം പൊടിയുകയോ ചെയ്യുന്നതുവരെ സൂചി മുന്നോട്ട കൊണ്ടുപോകുന്നു. എന്നിട്ട് സൂചിക്ക് മുകളിലൂടെ കത്തീറ്റർ കടത്തുന്നു.

ഡോപ്ലർ നിർദ്ദേശിത രീതി : ഡോപ്ലർ സഹായത്തോടെയുള്ള രീതി താഴെപ്പറയും വിധമാണ്. ഡോപ്ലർ ഉപകരണത്താൽ റേഡിയൽ ശുദ്ധരക്തധമനി പരമാവധി പ്രവാഹം (ശബ്ദം) ഉണ്ടാകുന്ന പ്രദേശം വഴി കണ്ടെത്തുന്നു. ട്യൂബ് കടത്തുന്ന പ്രക്രിയയിലുടനീളം ഡോപ്ലർ ഉപകരണം ശുദ്ധരരക്തധമനിക്കു മുകളിൽ ഉണ്ടാവും. ശുദ്ധരക്തധമനിയുടെ കൃത്യം സ്ഥാനം, സൂചി ശുദ്ധരക്തധമനിയിൽ അമരുമ്പോഴുണ്ടാകുന്ന ശബ്ദ വ്യതിയാനത്തിൽ നിന്ന് നിർണയിക്കും. സൂചി വീണ്ടും മുന്നോട്ട് നീക്കി ഡോപ്ലർ ശബ്ദം ശുദ്ധരക്തധമനിയുടെ പുനർ വികാസം പ്രകടമാക്കുകയോ സൂചിയിൽ രക്തം പ്രത്യക്ഷപ്പെടുകയോ ചെയ്യുന്നതുവരെ മുന്നോട്ട് കൊണ്ടുപോകും . അതിനു ശേഷം സൂചിക്കു മുകളിലൂടെ കത്തീറ്റർ കടത്തും.

അപകടങ്ങളും പാർശ്വഫലങ്ങളും എന്തെല്ലാം ?

റേഡിയൽ ശുദ്ധരക്തധമനിയിൽ കുഴൽ കടത്തുമ്പോഴുണ്ടാകുന്ന ഏറ്റവും സാധാരണമായ സങ്കീർണത താത്ക്കാലികമായി ധമനി അടയുക എന്ന താരതമ്യേന അപകടകരമല്ലാത്ത സങ്കീർണ്ണതയാണ്. പക്ഷേ ഗുരുതരമായ രക്തപ്രവാഹത്തിലെ കുറവുണ്ടായി വിരലോ അറ്റമോ മുറിച്ചു മാറ്റേണ്ടുന്ന അവസ്ഥയും ശ്രദ്ധിക്കപ്പെട്ടിട്ടുണ്ട്. (0.002 ശതമാനം സാധ്യത) കൈവെള്ളയിലെ തൊലി നശിക്കുക, രക്തം കട്ടപിടിക്കുക (14%), കലകൾ വിഘടിക്കുന്ന രോഗലക്ഷണം, രക്തധമനികളുടെ അയഥാർത്ഥമായ വികസനം(0.09%) എന്നിവയും ചിലപ്പോൾ ശ്രദ്ധയിൽ പെട്ടിട്ടുണ്ട്.

ഈ പഠനം എന്തിന് ?

ഹൃദയമിടിപ്പിലും രക്തപ്രവാഹത്തിലും വലിയ വ്യതിയാനങ്ങൾ സംഭവിക്കുന്ന ഹൃദയരോഗികളിൽ അന്ധമായ സ്പർശനത്തിലൂടെ കുഴൽ കടത്തുന്ന രീതിക്കുമേൽ ആധുനികമായ അൾട്രാസൗണ്ട് ഡോപ്ലർ രീതികളുടെ ഉപയോഗക്ഷമത കണ്ടെത്തുന്നതിനാണ് ഞങ്ങൾ ഈ പഠനം നടത്തുന്നത്.

പഠനം ആരംഭിച്ചശേഷം താങ്കൾക്ക് പിൻമാറാമോ ?

താങ്കളുടെ പഠനത്തിലുള്ള പങ്കാളിത്തം പൂർണമായും സ്വമേധയാ ഉള്ളതും പഠനത്തിൽ നിന്ന് പിൻമാറാൻ സ്വാതന്ത്ര്യം ഉള്ളതും ആണ്. അങ്ങനെ ചെയ്യുന്നതുകൊണ്ട് ഈ ആശുപത്രിയിലെ താങ്കളുടെ സാധാരണ ചികിത്സയെ ബാധിക്കുകയില്ല.

പഠനാനുബന്ധിയായ അപകടം ഉണ്ടായാൽ എന്തു സംഭവിക്കും ?

ഞങ്ങൾ ഒരു അപകടവും പ്രതീക്ഷിക്കുന്നില്ല. പക്ഷേ പഠനത്തിന്റെ ഫലമായി താങ്കൾക്ക് എന്തെങ്കിലും പാർശ്വഫലങ്ങളുണ്ടായാൽ താങ്കൾക്ക് ഒരു ചെലവും ഉണ്ടാകാത്തവിധം ചികിത്സിക്കും. എന്തായാലും ഞങ്ങൾക്ക് സാമ്പത്തിക നഷ്ടപരിഹാരം നൽകാനാവില്ല.

ഈ പഠനത്തിന് താങ്കൾ പണം മുടക്കണോ ?

വേണ്ട

താങ്കളുടെ വ്യക്തിപരമായ വിവരങ്ങൾ രഹസ്യമായി വയ്ക്കുമോ ?

പഠനഫലങ്ങൾ ഒരു വൈദ്യശാസ്ത്ര ജേർണലിൽ പ്രസിദ്ധീകരിക്കുമെങ്കിലും താങ്കളുടെ പേരു വിവരങ്ങൾ ഉണ്ടാവില്ല. എന്നാൽ താങ്കൾ ഈ പഠനത്തിൽ പങ്കെടുക്കുന്നുവെങ്കിൽ താങ്കളുടെ സമ്മതമില്ലാതെ തന്നെ ഈ പഠനവുമായി ബന്ധപ്പെട്ട ആളുകൾക്ക് പരിശോധനാഫലങ്ങൾ വിലയിരുത്താം.

താങ്കൾക്ക് കൂടുതൽ എന്തെങ്കിലും ചോദ്യങ്ങൾ ഉണ്ടെങ്കിൽ ദയവായി ഞങ്ങളോട് ചോദിക്കുക

ഡോ. സുധദേവ് റോയ്, സീനിയർ റസിഡന്റ്സ് കാർഡിയാക് അനസ്തേഷ്യ (ടെലിഫോൺ : 9645206961) അല്ലെങ്കിൽ ഇ.മെയിൽ suddha@sctimst.ac.in

ഡോ.പ്രശാന്തകുമാർ ഡാഷ്, പ്രൊഫസ്സർ കാർഡിയാക് അനസ്തേഷ്യ (ടെലഫോൺ 09349336584)

ഡോ.രൂപ ശ്രീധർ, പ്രൊഫസർ, ഡിപ്പാർട്ട്മെന്റ് ഓഫ് കാർഡിയാക് അനസ്തേഷ്യ, (ടെലഫോൺ : 944631 4043)

പ്രസ്താവന

ഞാൻ .... (കോളങ്ങൾ അടയാളപ്പെടുത്തുക)പങ്കെടുക്കുന്നയാളിന്റെ പേര്

ജനനത്തീയതി/ വയസ്സ് (വർഷത്തിൽ)

പഠനസംബന്ധിയായി എനിക്കു നൽകിയ വിവരങ്ങൾ വായിച്ചും എന്നു ഞാൻ പ്രസ്താവിക്കുന്നു.

റേഡിയൽ ശുദ്ധരക്തധമനിയിലെ കുഴൽ കടത്തലിന്റെ മൂന്ന് വ്യത്യസ്തരീതികളുടെ താരതമ്യം ഒരു ദീർഘവീക്ഷണത്തോടെയുള്ള ക്രമരഹിതപഠനം. എന്റെ എല്ലാ സംശയങ്ങളും പരിഹരിച്ചു. [ ]

എന്റെ ഈ പഠനത്തിലുള്ള പങ്കാളിത്തം പൂർണമായും സ്വമേധയാ ഉള്ളതാണെന്നും എന്റെ ചികിത്സയെയോ നിയമഅവകാശങ്ങളെയോ ബാധിക്കാതെ പഠനത്തിൽ നിന്നും പിൻമാറാമെന്നും ഞാൻ മനസ്സിലാക്കുന്നു. [ ]

ഞാൻ ഈ പഠനത്തിൽ നിന്നും പിൻമാറിയാലും പഠനം നടത്തുന്നവർക്കും സ്ഥാപനത്തിലെ നൈതിക കമ്മിറ്റി അംഗങ്ങൾക്കും എന്റെ ആരോഗ്യരേഖകൾ പരിശോധിക്കുന്നതിന് എന്റെ അനുവാദരേഖകൾ ആവശ്യമില്ലെന്ന് ഞാൻ മനസ്സിലാക്കുന്നു. അതിനോട് ഞാൻ യോജിക്കുന്നു. [ ]

എന്നെ തിരിച്ചറിയാനുതകുന്ന വിവരങ്ങൾ ഒന്നും മറ്റുള്ളവർക്കു നൽകുകയോ പ്രസിദ്ധീകരിക്കുകയോ ചെയ്യില്ലെന്ന് ഞാൻ മനസ്സിലാക്കുന്നു. [ ]

ഞാൻ സ്വമേധയാ പഠനത്തിൽ പങ്കെടുക്കാൻ സമ്മതിക്കുന്നു [ ]

സമ്മതപത്രത്തിന്റെ ഒപ്പിട്ട ഒരു കോപ്പി എനിക്കു കിട്ടി [ ]

പേര്

ഒപ്പ്

തീയതി

സാക്ഷിയുടെ പേര്

പങ്കെടുക്കുന്ന ആളുമായുള്ള ബന്ധം

തീയതി

(സമ്മതം വാങ്ങുന്നയാൾ) മെഡിക്കൽ റിസർച്ച് പ്രോജക്ടിനാവശ്യമായ സമ്മതപത്രത്തിനുവേണ്ടുന്ന എല്ലാ ഘടകങ്ങളും തൃപ്തികരമായി നിർവഹിച്ചിരിക്കുന്നുവെന്ന് ഞാൻ ബോധ്യപ്പെടുത്തുന്നു. പഠനപങ്കാളിയുമായി ഗവേഷണപദ്ധതിയെപ്പറ്റി സാങ്കേതികേതര പദങ്ങളുപയോഗിച്ച് എല്ലാ വിവരങ്ങളെപ്പറ്റിയും ചർച്ച നടത്തുകയും പ്രതീക്ഷിക്കാവുന്ന അപകടസാധ്യതകളും പാർശ്വഫലങ്ങളും വിശദീകരിക്കുകയും ചെയ്തു. പങ്കാളിയെ ചോദ്യങ്ങൾ ചോദിക്കാൻ പ്രേരിപ്പിക്കുകയും എല്ലാ ചോദ്യങ്ങൾക്കും ഉത്തരം നൽകുകയും ചെയ്തു എന്നും ഞാൻ സാക്ഷ്യപ്പെടുത്തുന്നു.

സമ്മതപത്രം വാങ്ങുന്ന ആളുടെ പേരും ഒപ്പും .

Case record form / Proforma

Patient sticker

Name –

Age –

Sex –

Weight-

Height –

BMI-

Disease/Lesion –

Ejection Fraction –

Premedication given – Yes / No

Time to cannulate (in seconds) –

Number of attempts for successful cannulation –

Was cannulation possible in 10 minutes – Yes / No

Vitals before and after cannulation -

	Heart Rate	(NIBP)	SpO_2
Before Cannulation			
After Cannulation			

NIBP = Non-invasive Blood Pressure

Any complication –

	Post-operative Day	Hours after cannulation
Thrombosis		
Distal discoloration		
Hematoma		
Cannulation site infection		
Blockage of artery		

IEC Approval

श्री चित्रा तिरुनाल आयुर्विज्ञान और प्रौद्योगिकी संस्थान
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THIRUVANANTHAPURAM - 695 011, INDIA
(An Institute of National importance under Govt. of India)

Institutional Ethics Committee (IEC)
(IEC Regn No. ECR/189/Inst/KL/2013)

SCT / IEC- 547/ FEBRUARY-2014 — 03-04-14

Dr. Suddhadeb Roy
Senior Resident
Department of Anesthesia
SCTIMST.

Dear Dr. Suddhadeb Roy,

The Institutional Ethics Committee reviewed and discussed your application to conduct the study entitled "COMPARISON OF THREE DIFFERENT METHODS OF RADIAL ARTERY CANNULATION: A PROSPECTIVE RANDOMIZED STUDY. (IEC-547)" on 14th February, 2014.

The following documents were reviewed:

1. *Covering letter dated 28.11.2013 addressed to the Chairman of IEC regarding the submission of the documents for IEC approval.*
2. *IEC Application form.*

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तार : चित्रमेट — फोन — फाक्स — ई-मेइल
Grams : Chitramet — Phone : 2443152 — Fax : (91)471-2446433 2550728 — E-mail : sct. @sctimst.ker.nic.in

3. *Technical Advisory Committee's Approval Letter.*
4. *Study Proposal.*
5. *Informed Consent Form in English.*
6. *Informed Consent Form translated to Malayalam.*
7. *Short CV's of the Principal Investigator and Co- Principal Investigator.*
8. *Letter addressed to the Chairman, IEC-SCTIMST dated 02-04-14 from Dr. Suddhadeb Roy, Senior Resident, Department of Cardiac Anaestheisiology, SCTIMST submitting the modified consent forms in Malayalam and English.*
9. *Modified consent forms in English and Malayalam.*

The following members of the Ethics Committee were present at the meeting held on 14th February, 2014 at G.Parthasarathi Board Room, AMCHSS, SCTIMST.

Sl. No	Member Name	Highest Degree	Gender	Scientific / Non-scientific	Affiliation with Institution (s)
1.	Justice M.R. Hariharan Nair.	MA BL	Male	Legal Expert (Chairperson)	No
2.	Dr. J. M. Tharakan	MD	Male	Clinician (Cardiologist)	Yes
3.	Dr. K. A. Kumar	MD	Male	Clinician (Psychiatrist)	No
4.	Dr. Rema M. N	MD	Female	Pharmacologist	No
5.	Dr. Meenu Hariharan	DM	Female	Clinician (Gastro Enterologist)	No
6.	Dr.R. V. G Menon	PhD	Male	Lay Person	No

7.	Dr. Premila P.G.	MD	Female	Clinician (Paediatrician)	No
8.	Dr. S.Sivasankaran	MD	Male	Clinician (Cardiologist)	Yes
9.	Dr. Anoopkumar Thekkuveettil	PhD	Male	Basic Scientist (Molecular Biology) /Ethicist (Member Secretary)	Yes

IEC Decision

Approved the conduct of the study in the present form.

Remarks:

The Institutional Ethics Committee expects to be informed about the progress of the study, any SAE occurring in the course of the study, any changes in the protocol and patient information/informed consent and asks to be provided a copy of the final report.

There was no member of the study team who participated in voting / decision making process. The ethics committee is organized and operated according to the requirements of Good Clinical Practice and the requirements of the Indian Council of Medical Research (ICMR).

Yours Sincerely

Dr. Anoopkumar Thekkuveettil
Member Secretary, Ethics Committee.

Plagiarism Check Report

Thesis Dr Suddhadeb Roy.docx

ORIGINALITY REPORT

13%

SIMILARITY INDEX

PRIMARY SOURCES

TIME SUBMITTED	25-SEP-2015 03:57PM
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Master Chart

Palpation Group

Serial No	Age	Sex	Height	Weight	BMI	Disease	EF (%)	Premed given	Time to cannulate	Attempts	Cannulation possible
1	41	M	171	50	17.22	CAD	54	Y	67	2	Y
2	47	M	160	48	18.90	CAD	65	Y	77	1	Y
3	47	M	167	51	18.40	CAD	64	Y	72	2	Y
4	57	F	154	51	21.37	Valve	60	Y	83	1	Y
5	45	M	167	53	18.98	CAD	57	Y	82	1	Y
6	52	M	161	53	20.38	CAD	64	Y	87	2	Y
7	49	F	139	61	31.71	Valve	61	Y	78	1	Y
8	59	M	170	50	17.23	CAD	67	Y	68	1	Y
9	52	M	167	45	16.10	CAD	56	Y	81	1	Y
10	54	M	152	54	23.19	Valve	52	Y	44	1	Y
11	37	F	155	49	20.63	CAD	62	Y	63	2	Y
12	46	M	171	49	16.82	CAD	60	Y	73	1	N
13	50	M	171	54	18.70	CAD	59	Y	72	2	Y
14	47	F	152	57	24.40	Valve	58	Y	80	1	Y
15	39	M	160	43	16.88	CAD	56	Y	62	1	Y
16	47	M	145	57	27.17	CAD	66	Y	79	1	Y
17	41	F	159	52	20.53	Valve	62	Y	84	2	Y
18	41	M	165	52	19.05	CAD	70	Y	66	1	Y
19	38	M	162	57	21.61	Valve	57	Y	71	3	Y
20	53	M	166	47	17.26	CAD	57	Y	66	2	Y
21	46	F	158	55	21.88	Valve	56	Y	67	1	Y
22	42	M	174	56	18.52	Valve	57	Y	66	1	Y
23	41	F	150	56	25.20	CAD	64	Y	83	1	Y
24	51	F	169	63	21.82	Valve	63	Y	82	1	Y
25	38	M	168	58	20.60	Valve	55	Y	68	2	Y
26	49	M	168	53	18.87	CAD	73	Y	65	1	N
27	33	M	171	54	18.63	Valve	58	Y	90	2	Y
28	46	F	150	45	20.13	Valve	67	Y	79	2	Y
29	39	M	169	58	20.33	Valve	60	Y	94	1	Y
30	49	F	154	48	20.34	CAD	55	Y	73	1	Y
31	46	F	158	51	20.35	Valve	64	Y	73	1	Y
32	41	F	164	56	20.77	Valve	58	Y	79	1	Y
33	49	M	170	51	17.68	CAD	60	Y	75	2	Y
34	50	F	157	54	21.82	CAD	63	Y	84	1	Y
35	55	M	159	51	20.03	Valve	59	Y	71	2	Y
36	38	M	167	58	20.80	CAD	63	Y	78	2	Y
37	40	M	168	57	20.08	Valve	58	Y	71	1	Y
38	47	M	150	51	22.63	Valve	57	Y	64	1	Y

Serial No	HR BL	NIBP Sys BL	NIBP Dia BL	SpO_2 BL	HR AC	NIBP Sys AC	NIBP Dia AC	SpO_2 AC
1	73	158	93	100	80	157	99	100
2	70	149	94	100	74	152	89	100
3	66	141	93	100	77	164	96	100
4	68	161	89	100	74	153	98	99
5	68	169	96	100	76	162	93	100
6	75	148	92	100	67	152	105	100
7	69	154	92	99	75	161	100	100
8	76	146	96	100	65	168	99	100
9	74	154	90	100	82	150	94	100
10	73	144	97	100	70	156	92	99
11	75	143	82	100	72	158	99	100
12	68	145	91	99	76	154	99	99
13	74	161	91	100	73	150	93	100
14	71	154	89	100	76	164	91	100
15	70	157	96	100	92	154	98	100
16	70	159	90	99	82	153	97	100
17	78	135	99	100	71	162	98	100
18	70	142	99	100	67	158	99	99
19	79	149	90	100	76	154	98	100
20	68	152	91	100	81	156	100	100
21	76	151	96	99	79	153	98	100
22	65	146	99	100	80	162	97	100
23	72	148	92	98	67	152	103	100
24	72	159	92	100	71	154	97	99
25	72	147	84	100	82	158	95	100
26	74	155	93	99	69	160	96	100
27	74	159	97	100	77	161	99	100
28	71	153	105	100	81	158	99	100
29	72	137	87	100	81	157	96	100
30	76	149	95	100	68	154	95	99
31	78	158	89	100	80	160	98	100
32	77	141	94	100	77	151	98	100
33	73	146	96	100	72	163	94	100
34	74	146	92	100	75	159	95	100
35	72	146	94	100	73	157	99	100
36	61	153	90	100	75	162	93	100
37	64	146	89	100	79	155	98	100
38	69	153	92	100	82	159	97	100

Ultrasound (USG) Group

Serial No	Age	Sex	Height	Weight	BMI	Disease	EF (%)	Premed given	Time to cannulate	Attempts	Cannulation possible
1	30	M	164	48	17.84	CAD	68	Y	75	1	Y
2	46	M	171	49	16.64	Valve	59	Y	86	2	Y
3	47	M	162	45	17.03	Valve	66	Y	79	4	Y
4	43	F	158	50	19.91	Valve	61	Y	87	1	Y
5	40	M	158	51	20.33	CAD	62	Y	74	2	Y
6	46	F	144	48	23.13	CAD	59	Y	61	3	Y
7	51	M	161	54	20.89	Valve	59	Y	86	1	Y
8	46	M	167	59	20.97	CAD	63	Y	69	1	Y
9	45	M	168	59	20.88	Valve	63	Y	80	2	N
10	60	F	159	54	21.22	CAD	64	Y	71	2	Y
11	51	M	153	54	23.07	CAD	58	Y	78	2	Y
12	34	M	165	53	19.46	Valve	62	Y	71	2	Y
13	46	M	154	58	24.36	CAD	57	Y	73	1	Y
14	48	M	164	62	22.95	CAD	61	Y	65	3	Y
15	39	M	154	47	19.69	Valve	69	Y	79	1	Y
16	32	M	164	49	18.31	CAD	60	Y	59	3	N
17	53	M	159	48	19.05	CAD	61	Y	76	1	Y
18	47	M	160	57	22.39	CAD	63	Y	78	1	Y
19	46	M	159	48	19.12	Valve	66	Y	92	1	Y
20	54	M	157	49	19.87	Valve	62	Y	75	2	Y
21	42	F	147	46	21.21	CAD	62	Y	72	1	Y
22	51	M	159	49	19.23	Valve	62	Y	79	2	Y
23	48	M	158	49	19.54	CAD	71	Y	65	1	Y
24	49	M	163	45	16.98	Valve	64	Y	70	2	N
25	45	M	161	55	21.28	Valve	64	Y	69	2	Y
26	54	F	147	59	27.21	Valve	67	Y	77	3	Y
27	53	M	160	48	18.86	CAD	68	Y	88	1	Y
28	53	M	161	58	22.18	Valve	60	Y	76	3	Y
29	46	F	155	60	25.05	Valve	62	Y	67	1	Y
30	31	M	163	48	17.83	CAD	64	Y	76	1	Y
31	51	M	159	50	19.92	CAD	66	Y	79	2	Y
32	45	F	158	54	21.67	CAD	64	Y	68	1	Y
33	42	F	159	51	20.18	Valve	60	Y	86	2	Y
34	45	F	155	51	21.20	Valve	61	Y	80	1	Y
35	36	F	151	61	26.72	Valve	62	Y	83	4	Y
36	55	F	148	51	23.48	Valve	61	Y	80	1	Y
37	39	M	158	51	20.57	CAD	63	Y	79	2	Y
38	45	F	149	44	19.82	Valve	59	Y	71	2	Y
39	44	M	158	53	21.31	Valve	61	Y	79	1	Y

Serial No	HR BL	NIBP Sys BL	NIBP Dia BL	SpO_2 BL	HR AC	NIBP Sys AC	NIBP Dia AC	SpO_2 AC
1	72	150	87	100	72	160	97	100
2	73	161	95	100	81	159	98	100
3	70	148	91	100	71	158	101	100
4	72	157	89	100	74	161	100	99
5	70	150	93	100	73	156	96	100
6	70	158	90	100	79	161	90	100
7	69	150	88	100	71	160	97	100
8	77	140	93	100	79	159	92	100
9	71	148	90	100	78	160	98	100
10	68	156	95	100	79	158	95	100
11	72	149	96	100	83	153	95	100
12	71	149	90	100	75	156	96	100
13	67	156	89	100	72	159	102	100
14	70	152	94	99	68	160	101	99
15	70	150	88	100	77	164	105	100
16	70	155	90	99	80	157	103	100
17	79	144	97	100	74	158	89	100
18	74	154	92	100	78	154	105	100
19	72	160	96	100	79	159	92	100
20	73	153	90	100	71	156	98	100
21	73	148	90	100	74	157	95	100
22	69	146	90	100	75	160	101	100
23	74	146	93	100	75	155	102	100
24	75	145	92	100	70	164	103	100
25	74	153	94	100	72	158	99	100
26	72	141	94	99	76	158	98	100
27	71	157	90	100	74	154	86	100
28	75	146	91	100	76	159	87	100
29	75	158	92	100	75	160	94	100
30	73	151	93	100	76	156	95	98
31	71	154	94	100	77	157	95	100
32	72	154	91	99	74	161	97	100
33	75	148	95	100	71	156	95	100
34	71	149	92	100	73	165	105	100
35	73	155	93	100	72	160	100	100
36	71	154	92	100	73	156	95	99
37	73	151	96	100	76	160	92	100
38	72	153	90	100	76	158	98	100
39	72	144	93	100	83	158	91	100

Doppler Group

Serial No	Age	Sex	Height	Weight	BMI	Disease	EF (%)	Premed given	Time to cannulate	Attempts	Cannulation possible
1	44	M	157	46	18.70	CAD	62	Y	221	5	Y
2	39	M	153	55	23.37	Valve	52	Y	203	5	N
3	46	M	174	61	20.21	Valve	62	Y	215	4	Y
4	51	F	150	56	24.79	CAD	53	Y	249	1	Y
5	51	M	165	44	16.13	Valve	54	Y	189	4	Y
6	53	M	156	42	17.42	CAD	58	Y	205	4	N
7	35	M	156	59	24.45	CAD	54	Y	206	5	Y
8	44	F	147	59	27.41	CAD	59	Y	199	4	Y
9	50	M	153	57	24.16	Valve	64	Y	222	3	Y
10	40	M	154	56	23.76	CAD	57	Y	208	3	N
11	42	M	159	59	23.32	CAD	62	Y	209	3	Y
12	37	F	160	58	22.60	CAD	61	Y	213	4	Y
13	37	M	156	50	20.45	Valve	57	Y	204	6	N
14	41	F	152	55	23.62	CAD	60	Y	213	4	Y
15	41	F	152	55	23.81	CAD	60	Y	220	5	Y
16	35	M	154	52	22.00	Valve	63	Y	211	3	Y
17	42	M	159	54	21.34	CAD	56	Y	221	5	N
18	43	M	170	46	15.90	Valve	56	Y	211	1	Y
19	46	M	164	48	17.88	CAD	66	Y	208	4	Y
20	43	M	169	46	16.27	CAD	55	Y	209	3	N
21	43	F	172	58	19.70	CAD	51	Y	217	5	N
22	43	M	148	57	25.89	Valve	56	Y	216	4	Y
23	51	M	156	59	24.21	Valve	57	Y	222	5	Y
24	45	M	147	57	26.10	CAD	60	Y	217	4	Y
25	44	M	158	54	21.52	Valve	61	Y	226	3	Y
26	43	F	148	58	26.53	CAD	63	Y	217	4	N
27	54	M	160	49	19.19	Valve	67	Y	221	4	N
28	49	M	179	45	13.99	Valve	56	Y	217	2	Y
29	56	F	147	52	23.76	Valve	59	Y	205	3	Y
30	42	F	164	58	21.40	CAD	66	Y	208	4	Y
31	40	M	157	48	19.28	Valve	55	Y	199	1	Y
32	46	F	148	44	20.16	Valve	58	Y	214	3	Y
33	43	F	167	58	20.84	CAD	60	Y	198	6	N
34	42	F	156	46	18.84	CAD	57	Y	195	3	Y
35	50	M	164	51	18.98	Valve	56	Y	209	3	N
36	42	F	150	54	23.91	Valve	62	Y	227	5	N
37	44	M	157	49	20.08	Valve	57	Y	210	4	Y
38	51	F	155	56	23.24	CAD	59	Y	217	5	Y
39	50	M	157	57	23.07	CAD	58	Y	216	6	N

Serial No	HR BL	NIBP Sys BL	NIBP Dia BL	SpO_2 BL	HR AC	NIBP Sys AC	NIBP Dia AC	SpO_2 AC
1	79	159	89	100	77	162	99	100
2	68	155	92	100	79	159	102	100
3	76	159	96	99	76	155	101	98
4	65	153	97	100	79	150	98	100
5	72	156	93	100	77	165	94	100
6	68	154	93	100	73	162	104	100
7	84	148	95	100	85	166	98	100
8	70	157	88	100	77	165	97	99
9	68	160	99	100	78	156	103	100
10	71	158	97	100	77	151	96	100
11	70	149	99	100	76	156	97	99
12	71	154	93	100	79	155	102	100
13	78	152	89	100	71	166	103	100
14	74	156	93	100	78	159	104	99
15	72	150	94	99	71	163	90	100
16	65	155	91	100	79	162	97	100
17	69	153	94	100	77	163	99	100
18	71	140	93	100	78	163	99	99
19	71	151	96	100	80	160	98	100
20	73	154	91	100	81	160	101	100
21	78	144	95	100	73	162	101	100
22	79	163	90	100	79	154	103	100
23	73	147	94	100	80	156	104	100
24	75	156	96	100	77	159	97	100
25	69	151	95	100	71	161	98	100
26	69	153	99	98	79	155	95	99
27	71	151	86	100	77	152	99	100
28	70	158	90	100	75	161	97	100
29	72	143	88	100	75	169	94	100
30	70	158	98	100	81	161	104	100
31	74	160	89	99	79	160	92	100
32	71	149	94	100	76	160	99	100
33	75	147	97	100	78	161	97	99
34	70	157	89	100	77	169	100	100
35	75	153	103	100	78	147	101	100
36	78	155	93	100	72	169	100	100
37	71	146	96	100	73	151	98	100
38	72	152	97	100	77	158	93	100
39	77	158	95	100	81	159	101	100