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Original Contribution

Optimal wrist positioning for radial arterial cannulation in adults: A systematic review and meta-analysis

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ABSTRACT

Background: Wrist extension is commonly taught as part of the radial artery cannulation technique. Currently the degree of wrist extension required to optimize cannulation success remains inconclusive. This is the first meta-analysis to investigate optimal wrist positioning for radial artery cannulation.
Methods: Five major databases (CINAHL, SCOPUS, PubMed, Medline and Web of Science) were systematically searched until June 2016. All studies were assessed for level of evidence and risk of bias. The data for each outcome was then assessed via a meta-analysis.
Results: Five studies including 500 patients were found. There is moderate evidence to support 45° wrist angulation for improved radial artery cannulation. Radial arterial height is likely to be increased at 45°, cannulation time is significantly faster and success rates are likely higher than at other degrees of angulation. However, this evidence is confounded by the significant heterogeneity (I^2 >75%) which is at least in part related to a high proportion of healthy young volunteers who were amongst the studied populations.
Conclusion: This review found moderate evidence in support of a 45° wrist angulation to facilitate arterial cannulation, however the results are largely limited by the external validity of the data collected given the restrictive populations studied. Any further studies investigating the effect of altering wrist angulation on radial artery cannulation should focus on populations who are either likely to require arterial cannulation or predisposed to difficult access.

1. Introduction

The most common location for invasive blood pressure monitoring and arterial blood sampling in the critical care setting is the radial artery [1]. Radial artery cannulation is generally safe procedure, however a small percentage of patients experience infectious, thrombotic or mechanical complications and the incidence of these complications increases with each additional attempt [2]. The use of ultrasound has recently been shown to be a best practice as an adjunct to radial artery cannulation [3]. This translates into a significantly improved first attempt success rate and a reduction in the mean number of attempts required.

Current studies show that on average between one and three attempts using ultrasound guidance are required for successful cannulation [3]. With this in mind there have been a number of studies investigating other aspects of the radial artery cannulation process. A recent meta-analysis by Gao and colleagues showed no evidence to support either the long-axis in-plane or short-axis out-of-plane techniques [4]. Another aspect that may influence first attempt success rate of radial artery cannulation is the angle at which the wrist is bent during the procedure.

A commonly cited cause of failure to cannulate under ultrasound guidance is small radial artery diameter [5]. Several studies have been performed investigating the effect of wrist angle on radial artery size and ultimately first pass success. Currently, there are no meta-analyses providing a concise summary of this growing body of literature. The aim of this review is to determine whether there is an optimum wrist angle for radial artery cannulation as determined by radial artery measurements and cannulation success.

2. Methods

2.1. Search strategy

Five databases (CINAHL, SCOPUS, PubMed, Medline and Web of Science) were independently searched from their inception until June 2016. This systematic search was conducted independently by TM and LW. The search terms included:

(1) (radial (artery OR arterial)) AND (wrist (angle OR angulation OR position OR positioning));

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0735-6757/

A manual reference and citation check of all papers and recent reviews was performed to identify any additional studies.

2.2. Inclusion and exclusion criteria

For inclusion into this review, all studies were required to report on measurements of the radial artery and/or successful radial artery cannulation. These outcome had to be measured secondary to differing wrist angles.

Two reviewers (TM and LW) independently assessed and agreed upon each study for inclusion in this systematic review.

We only included papers assessing adults, as pediatric radial artery anatomy differs substantially. We excluded any papers performing arterial punctures anywhere other than within 15 cm of the wrist, this approximates to the lower half of the forearm.

2.3. Data extraction

TM and LW independently extracted data from each of the included articles. The data extracted from each study included the study population demographics and co-morbidities, wrist angles, radial artery measurements and/or direct effect on radial artery cannulation. All data collected was then compared for homogeneity.

2.4. Level of evidence, risk of bias and outcome level of evidence ranking

Each articles level of evidence was evaluated using the Centre for Evidence Based Medicine (CEBM): Levels of Evidence [6]. These studies were then assessed for risk of bias and methodological quality using the Cochrane Collaboration's tool for assessing the risk of bias [7]. As dictated by the risk of bias, or other serious methodological flaws, Level of Evidence may then be downgraded as described in the Cochrane tool.

The results from each study were then grouped into individual outcomes.

2.5. Statistical analyses

RevMan 5.3 software was used to perform the data analysis (The Nordic Cochrane Centre, Copenhagen, Denmark). Differences in dichotomous outcomes were expressed as relative risk (RR), and continuous outcomes as a weighted mean difference (WMD), both with a 95% confidence interval (CI). The Mantel–Haenszel (M-H) random effects model was applied to the analysis. The I^2 statistic was used to assess heterogeneity, with an I^2> 50% indicating significance. A significant RR and WMD was defined as a p value <.05. Unless otherwise stated our in-text results are presented as either "[Mean Difference, 95% Confidence Interval, *P* value]" or "Mean Difference [95% CI, *P* value]".

3. Results

3.1. Literature search results

The systematic literature search yielded 235 citations, of which 36 were retrieved for review. These articles were selected for retrieval based on a review of their abstract, which appeared to meet the search criteria. Of these 36 articles, 6 met the inclusion criteria (Fig. 1). Notably, the paper by Mizukoshi et al [8], whilst eligible for inclusion could not be compiled into our meta-analysis as the data was only presented graphically without necessary numerical data. The authors were contacted for unpublished data to no success. The five remaining studies included 500 patients (Table). Each study was then screened for risk of bias and methodological quality using the Cochrane Collaboration's tool for assessing the risk of bias (Fig. 2). Of these five studies, two were high quality level one RCTs and three high quality, level one crossover studies (Table). Whilst crossover studies are not explicitly mentioned by the CEBM grading system we use, they fall under the level one 'n-of-1' banner and the inclusion of them as level one evidence is consistent with other groups' recommendations [9].

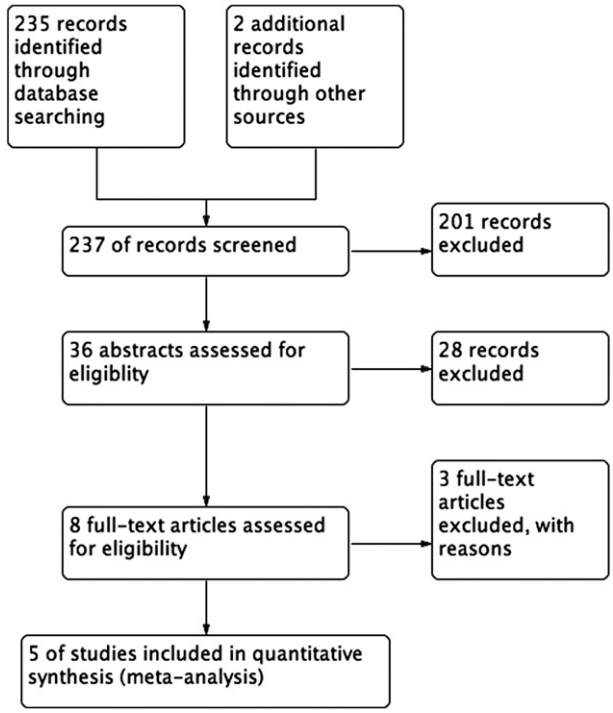

Fig. 1. Study identification algorithm outlining the filtering process from the literature search through to study inclusion.

4. Ultrasound measurement of the radial artery

4.1. Radial arterial height on ultrasound examination

There was conflicting evidence on the affect of wrist extension on RA height. Five level one papers assessed this outcome (Fig. 3). At 15° extension there was no significant effect of extension of RA size, with all three papers describing minimal non-significant effects. At 30° there was a borderline-significant increase in arterial height, with a mean difference 0.14 mm [0.00–0.29, $P = .05$]. One paper found reported a significant increase in the arterial height, one paper found a non-significant increase and the final paper found no effect. There was substantial heterogeneity, $I^2 = 70\%$.

At 45° there was incongruence between findings. Four papers reported this outcome, with two finding significant and large effect sizes, whilst two further papers reported no effect and a small, significant negative effect. Overall this angle on extension had the largest mean difference+ 0.30 mm, but was not statistically significant [−0.20 to 0.79, P = .24]. The data's heterogeneity was very high, $I^2 =$ 99%. Wrist extension beyond 60° found no significant change in RA height on ultrasound. Four papers assessed 60° extension, with two finding a small, positive significant effect, one paper finding no effect, and one reporting a small reduction in arterial height. Only two papers report on extension to 70–75°, with one paper finding a small significant effect and the other reporting no effect.

4.2. Sensitivity analysis results by age and by participant status

We undertook a sensitivity analyses of the data to re-examine difference in the studies populations. As 45° was the most heterogonous set of data, and examined by the most groups we present that information here. We re-analyzed the data based on participant age (Fig. A1) and participant type (hospital inpatient vs healthy volunteer) (Fig. A2).

There was a significant difference in the overall effect sizes observed base on the age of participants; in subjects less than 60 years old [0.11 mm, −0.35-0.57, $P = .64$] as opposed to those older [0.72 mm, 0.23–1.21, $P = .004$].

Table
Study characteristics

Study	Study type	Number of patients	Patient group	Intervention (no of pts)	Primary outcome(s)	Level of evidence*
Aydogan et al 2013 [10]	Cross-over Controlled Trial	152	Healthy Volunteers <50 years old	0° (152) 45° Ext. (152) 60° Ext. (152)	1) Radial Artery Height (US, SA & LA) 2) Radial Artery Width (US SA 3) Radial Artery Depth from Skin (US, SA & LA) 4) Radial Artery cross sectional area (US SA)	Level 1
Kucuk et al 2013 [11]	Cross-Over Controlled Trial	140	Healthy Volunteers 70 young (18–30 years old) 70 elderly (50–80 years old)	0° (140) 15° Ext. (140) 30° Ext. (140) 45° Ext. (140) 60° Ext. (140) 70° Ext. (140)	1) Radial Artery Height (US LA) 2) Radial Artery Depth from Skin (US LA)	Level 1
Kucuk et al 2014 [12]	RCT	100	Surgical or ICU Patients Requiring Arterial Access >60 years old	0° (20) 15° Ext. (20) 30° Ext. (20) 45° Ext. (20) 60° Ext. (20)	1) Radial Artery Height (US SA) 2) Radial Artery Depth from Skin (US SA) 3) Cannulation Time 4) First Attempt Success Rate 5) Number of Attempts 6) Success Rate	Level 1
Pandey et al 2012 [13]	RCT	60	Patients undergoing elective surgery 18–65 years old	30° Ext. (20) 45° Ext. (20) 60° Ext. (20)	1) Cannulation Time 2) First Attempt Success Rate 3) Number of Attempts 4) Success Rate	Level 1
Selvaraj et al 2015 [14]	Cross-Over Randomized Controlled Trial	48	Healthy Volunteers (All females <25 years old)	0° (48) 15° Ext. (48) 30° Ext. (48) 45° Ext. (48) 60° Ext. (48) 75° Ext. (48)	1) Radial Artery Height 2) Radial Artery Width 3) Radial Artery Depth from Skin	Level 1

* Level of evidence assessed using the Centre for Evidence Based Medicine (CEBM): Levels of evidence introduction document [6].

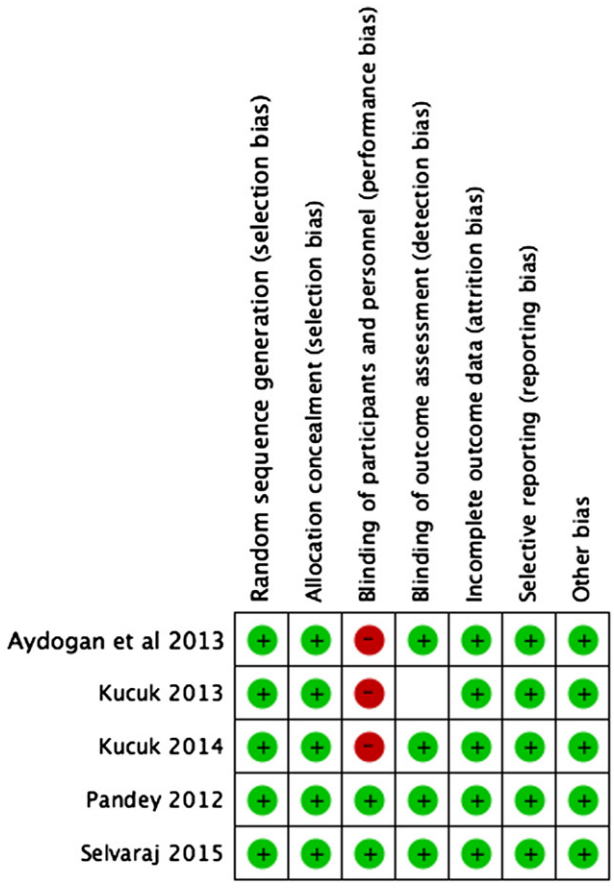

Fig. 2. Screening of bias and methodological quality based on the Cochrane Collaboration's tool for assessing the risk of bias.

Only one level one paper studied in-hospital patients and this was the paper that reported the greatest effect size.

4.3. Radial artery width and depth on ultrasound

Two level one papers reported on radial artery width with wrist angulation (Fig. A3). We found no significant effect on the width of the radial artery at 45° or 60° as compared to 0°.

Four papers assessed radial artery depth by ultrasound. The artery was significantly closer to skin at 45° [−0.29 mm, −0.52 to −0.05, $P = .02$] and 60° extension [−0.41 mm, −0.63 to −0.19, $P = .0003$] (Fig. 4). This effect was no longer apparent at extension beyond 60°. Overall, as in our other analyses this data was substantially heterogonous.

5. Clinical measures

Two papers, both level one high quality RCTs reported on the effects of wrist angulation on cannulation success (Fig. 5). This was measured by both papers as a combination of overall success rates, first pass success and cannulation time. One paper by Pandey and colleagues only compared 30°, 45° and 60°. We therefore report only on this range, using 45° as the control extension.

5.1. Cannulation time – Fig. 5

Our analysis showed that cannulation is significantly faster at 45° than at either 30° [7.36 s, 2.16–12.56, $P = .006$] or 60° [9.03 s, 4.25–13.81, $P = .0002$].

5.2. Success rate – Figs. A4 and A5

The first pass success rate was significantly higher at 45° than 30° [0.77, 0.61–0.98, $P = .03$]. There was a non-significant trend in favor of 45° when compared to 60° [0.79, 0.56–1.12, $P = .19$].

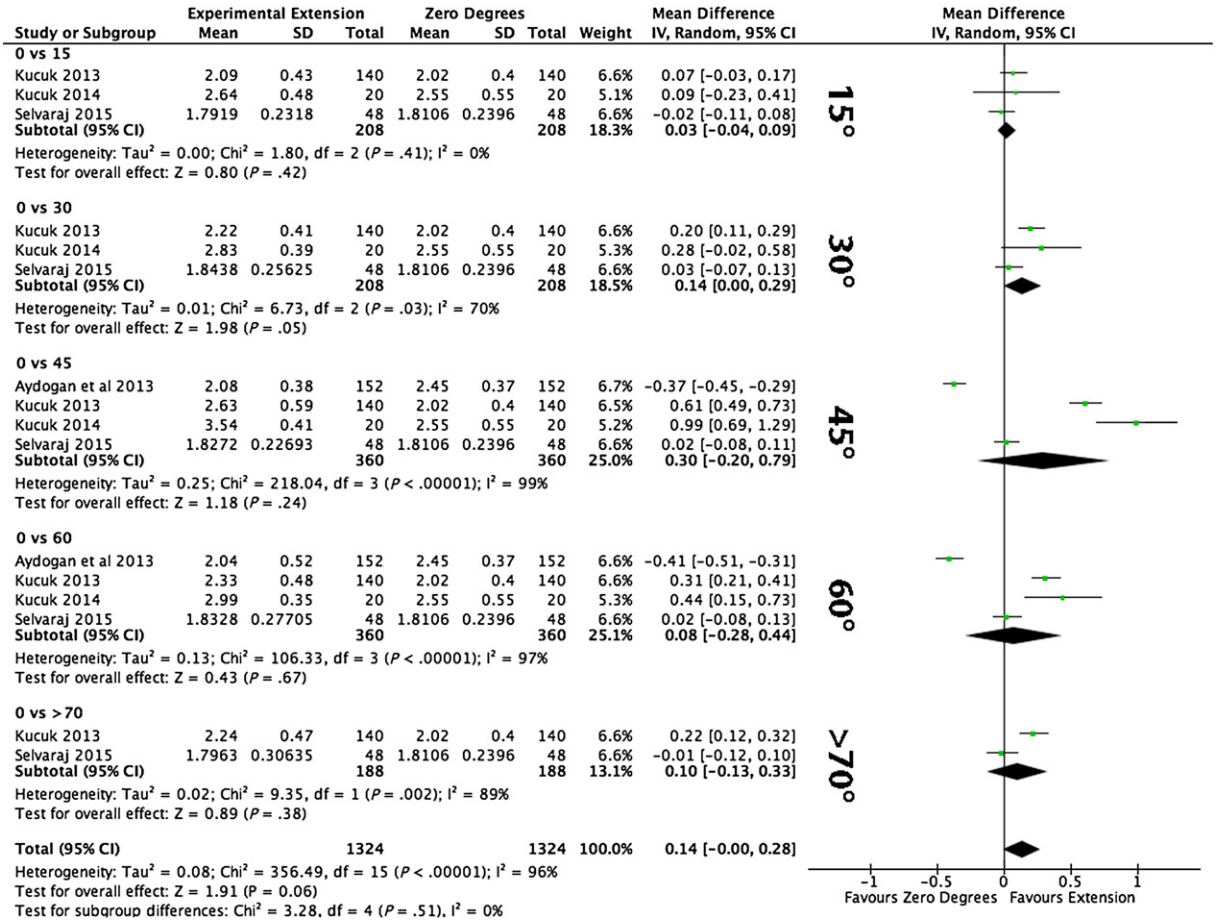

Fig. 3. Radial artery height on US, with varying extension of the wrist.

The rate of overall successful catheterization comparable across the three differing angulations assessed, with a small non-significant trend in favor of 45° extension.

6. Discussion

We undertook a systematic review and meta-analysis of studies comparing radial arterial access at varying angles of wrist extension. To our knowledge this is the first systematic review in this area and incorporates data from 500 patients. Overall the review demonstrated there is moderate evidence to support wrist extension at 45° and has highlighted potential future research directions.

Our meta-analysis suggests that wrist extension increases radial artery height. Whilst the amalgamated data does not reach clinical significance, there is a clear trend to increased arterial height with moderate wrist extension, which ten diminishes once the wrist is extended past 60°. The greatest mean effect was seen at 45° [+0.3 mm, $P = .24$].

The heterogeneity of the data motivated us to closely examine relevant subgroups amongst the studies. We undertook a sensitivity analysis, and found there were substantial differences in the effect of wrist angulation in subjects with a mean age of less than 60 years old when compared to those over 60 (Fig. A1).

We also reanalyzed the results by participant type, whether they were healthy volunteers or in-patients in hospital. Only one of the included studies that utilized ultrasound examined patients in hospital requiring arterial line catheterization (Fig. A2), and qualitatively it is of interest to note that this is the same study that demonstrate the greatest effect size.

Our subgroup analysis suggests that there may be substantial differences in the behavior of the vasculature of healthy volunteers and elderly or in-hospital patients. We would suggest that one potential explanation for the effects observed here and the data heterogeneity is that in the young, healthy volunteers' wrist angulation may have little effect on arterial size. It is possible that as people age and develop vascular disease extrinsic factors such positioning may have a larger role to play in achieving successful and non-traumatic cannulation.

Indeed it is of interest to note that one study by Aydogan and colleagues studied volunteers less than 50 years of age, but actually specifically excluded participants with peripheral vascular disease; they do not elaborate on the reasoning behind this exclusion criteria.

Of course those in hospital, or out of hospital with multiple comorbidities are the very people who are most likely to require arterial cannulation. Given the differences in effect across different study populations, as shown by the heterogeneity of effect size and our sensitivity analyses, we must consider the external validity of some of the study data included in this review may be very low.

Our meta-analysis of the clinical evidence also provides moderate evidence that wrist extension to 45° is superior for facilitating radial artery cannulation. Cannulation time was significantly shorter at 45° than at either 30° or 60° (Fig. 5) and there were non-significant trends towards improved first-pass success (Fig. A4) and overall success (Fig. A5).

The compiled data also supports the concept that the radial artery moves superficially as the wrist is extended, at least up to 60° extension (Fig. 4). At each incremental extension of the wrist, the artery appears to move more superficially, until at 60° the mean difference in depth was −0.41 mm [−0.63 to −0.19, $P = .0003$].

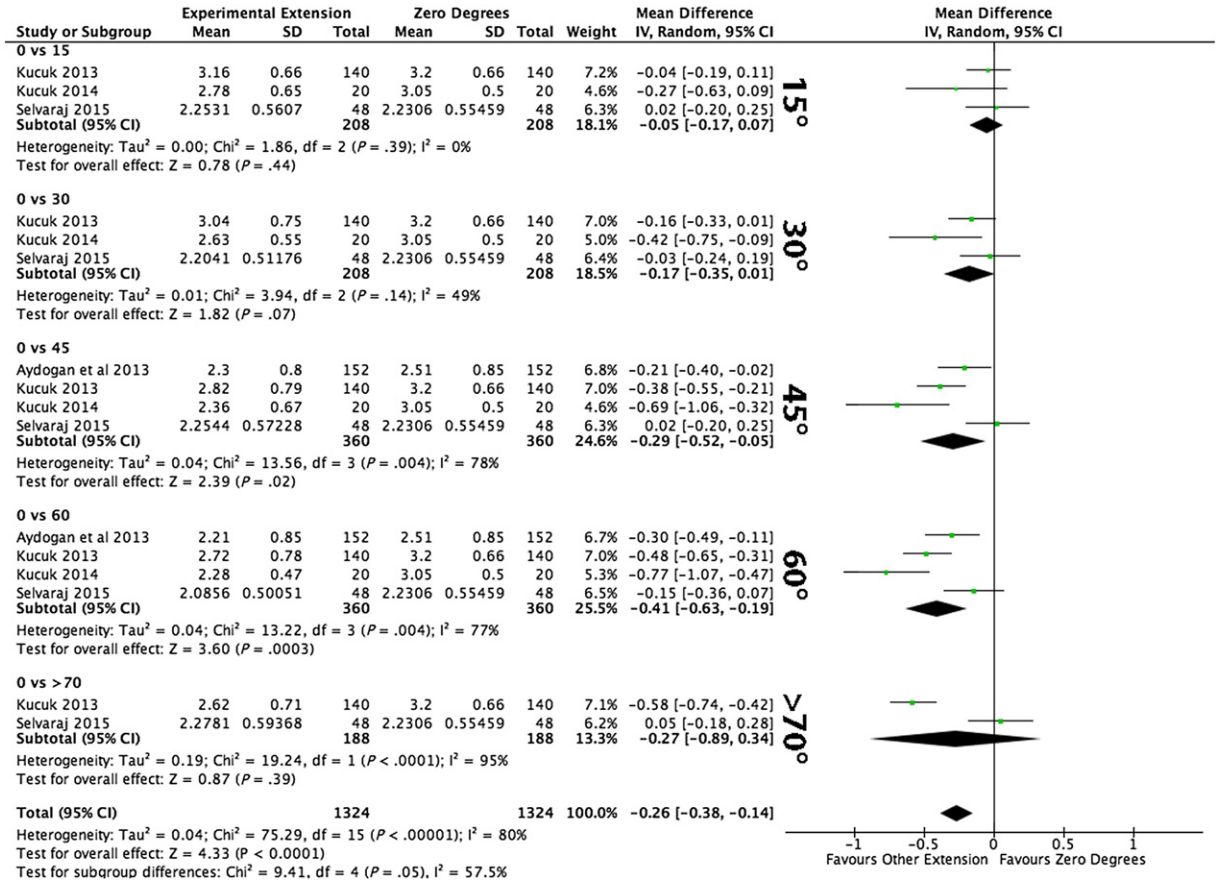

Fig. 4. Radial artery depth from skin to arterial wall on US, with varying extension of the wrist.

This data also relies in part on surrogate measures for arterial catheterization success, those of arterial dimensions on ultrasound. Vessel diameter is only one parameter that is cited to contribute to successful catheterization. Others aspects such as palpability of the pulse and tortuosity or the arterial course were not considered here.

We suggest that future studies could focus on assessing arterial parameters of those who are likely to receive arterial lines, for example hospital inpatients or outpatient volunteers with comorbidities that predispose them to periods of illness in hospital. Most importantly further research needs to be done investigating whether wrist angle alteration contributes to improved success rate in difficult populations (eg, the obese or those with peripheral arterial disease).

7. Conclusion

There is moderate evidence to support 45° wrist angulation to facilitate radial artery cannulation. However, this evidence is confounded by the significant heterogeneity that is likely attributed to the high percentage of healthy young volunteers who were studied. Our knowledge base would be well served if future studies focused on populations predisposed to difficult radial artery cannulation.

Conflict of Interest

The authors have no conflicts of interest to declare.

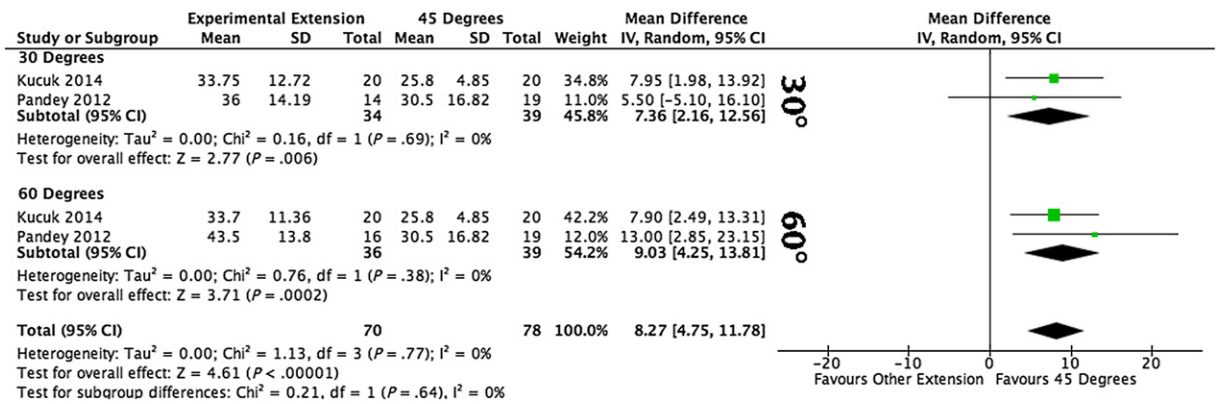

Fig. 5. Cannulation time at varying extension of the wrist, 30° and 60° vs 45°.

Appendix

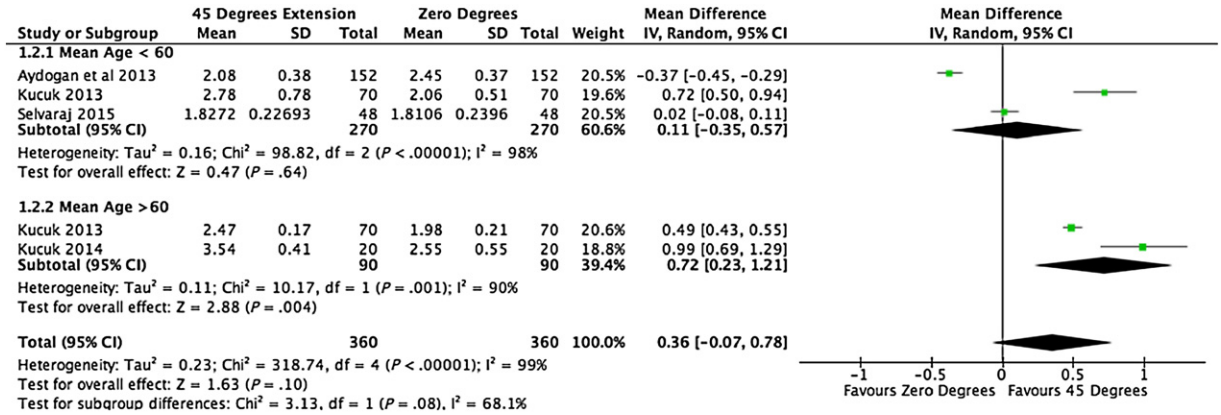

Fig. A1. Radial artery height on us, 45 degrees vs 0 degrees, sensitivity analysis by participant age.

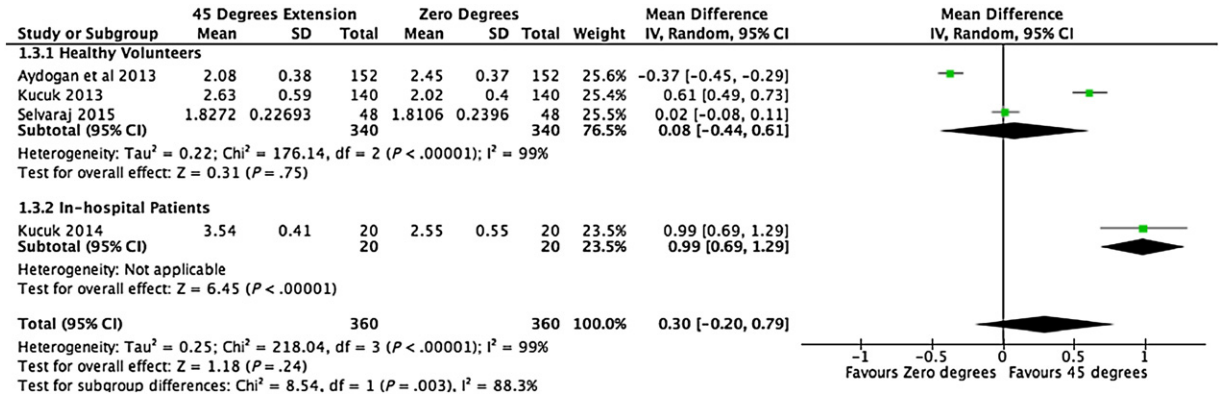

Fig. A2. Radial artery height on US, 45 degrees vs 0 degrees, sensitivity analysis by participant type.

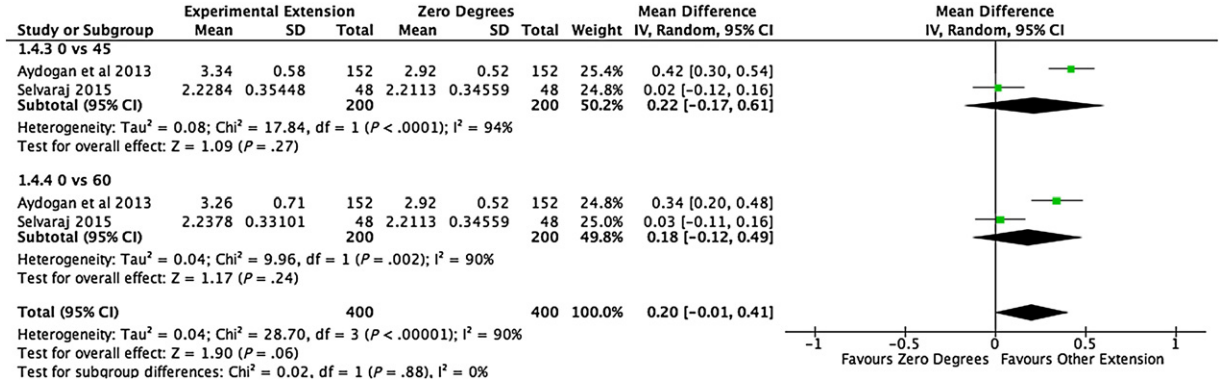

Fig. A3. Radial artery width on US at 45 or 60 degrees as compared to 0 degrees.

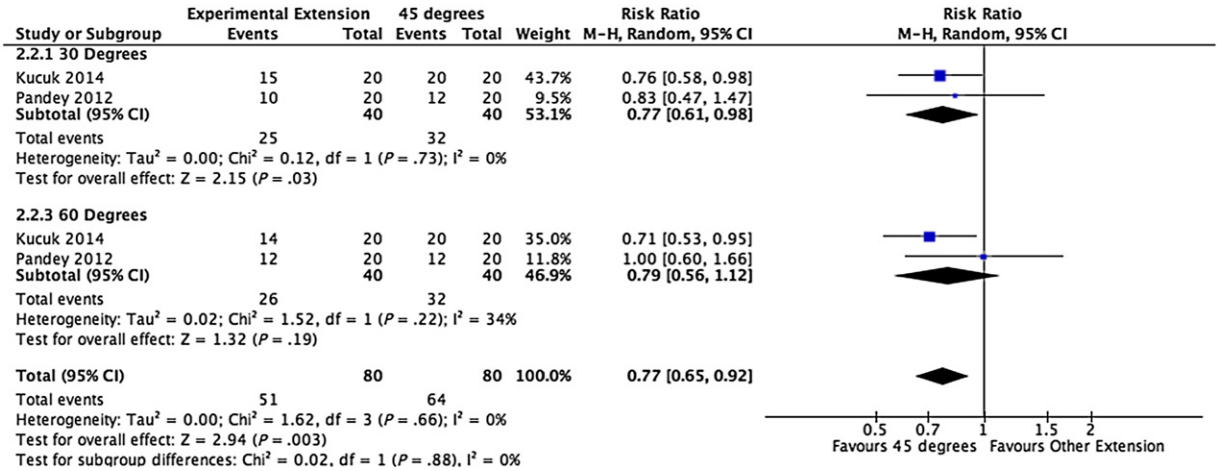

Fig. A4. First pass success rate at varying angles of wrist extension, 30° and 60° vs 45°.

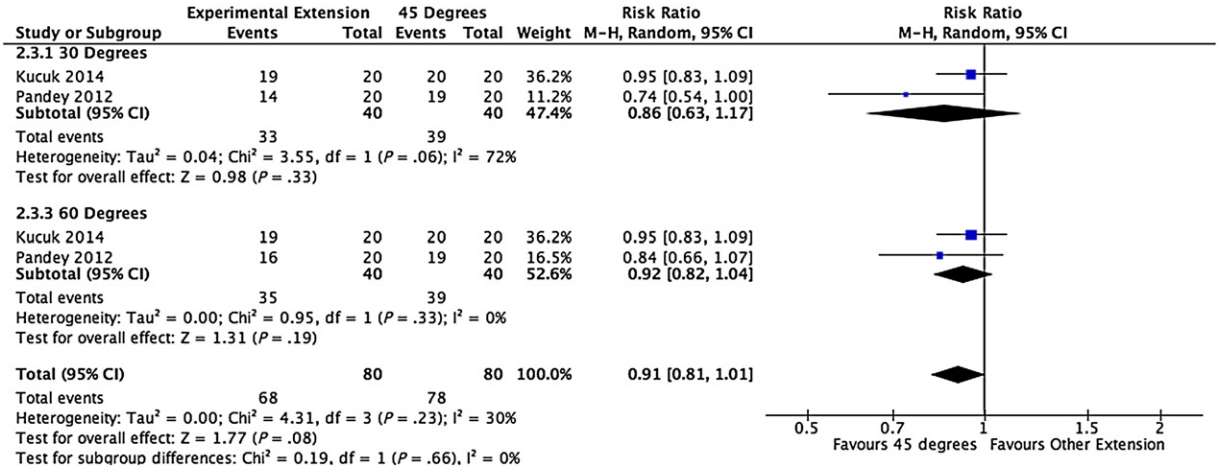

Fig. A5. Overall success rate at varying angles of wrist extension, 30° and 60° vs 45°.

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