

Ultrasound simulation of internal jugular vein cannulation in pregnant and non-pregnant women

Simulation par ultrasons de la canulation de la veine jugulaire interne chez les femmes enceintes et non enceintes

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Abstract

Background Pregnancy alters the anatomic landmarks for internal jugular vein (IJV) cannulation. In this study, IJV cannulation was simulated, and success of the technique was evaluated using ultrasound.

Methods Term pregnant women and non-pregnant female volunteers were recruited. The degree of difficulty in assessing neck anatomy was noted. The optimal insertion points for cannulation were marked on the skin of each subject according to the central landmark and palpatory techniques. The midpoint of a 15–10 MHz linear transducer was placed over each insertion point, and the vertical cursor of the ultrasound, which represented the path of the needle, was placed in the image. The outcome was an IJV puncture, a carotid artery (CA) puncture, or a missed attempt.

Results One hundred and sixty-one women, 99 pregnant and 62 non-pregnant, were studied. The identification of landmarks was more difficult in pregnant women ($P = 0.01$). The rates of successful IJV punctures, CA punctures, and missed attempts did not differ significantly between pregnant and non-pregnant women. Carotid artery punctures using the central landmark technique in

pregnant and non-pregnant subjects were 19% and 10%, respectively. Corresponding figures for the palpatory approach were 6% and 3%, respectively. The degree of IJV overlap of the CA in the palpatory technique was greater in pregnant women (38% vs 18% showed > 75% overlap; $P < 0.001$), a difference that remained after controlling for body mass index.

Conclusion The IJV overlies the CA to a greater extent in pregnant patients than in non-pregnant patients. Thus, a landmark approach for IJV cannulation might expose pregnant women to a greater risk of carotid puncture. This trial was registered at www.clinicaltrials.gov (NCT T00464828).

Résumé

Contexte La grossesse modifie les repères anatomiques nécessaires à réaliser une canulation de la veine jugulaire interne (VJI). Dans cette étude, nous avons simulé une canulation de la VJI et évalué la réussite de la technique par ultrasons.

Méthode Des femmes enceintes à terme et des volontaires non enceintes ont été recrutées. Le degré de difficulté de l'évaluation de l'anatomie du cou a été noté. Les points d'insertion optimaux pour la canulation ont été marqués sur la peau de chaque participante selon les techniques de repère central et de palpation. Le point médian d'un transducteur linéaire de 15–10 MHz a été placé sur chaque point d'insertion, et le curseur vertical de l'ultrason, qui représentait le chemin de l'aiguille, a été positionné sur l'image. Le critère d'évaluation était une ponction de la VJI, une ponction de l'artère carotide (AC), ou une tentative manquée.

Résultats Cent soixante et une femmes, dont 99 enceintes et 62 non enceintes, ont pris part à l'étude. L'identification des repères a été plus difficile chez les femmes enceintes

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($P = 0,01$). Les taux de ponctions de la VJI réussies, de ponctions de l'AC et de tentatives manquées n'ont pas été significativement différents entre les femmes enceintes et non enceintes. Les taux de ponction de l'artère carotide en utilisant la technique du repère central chez les femmes enceintes et non enceintes étaient de 19% et 10%, respectivement. Les résultats correspondants pour l'approche par palpation étaient de 6% et 3%, respectivement. Le degré de superposition de la VJI et de l'AC en technique de palpation était plus élevé chez les femmes enceintes (38% vs 18% ont montré une superposition >75%; $P < 0,001$), une différence qui est demeurée après avoir vérifié l'indice de masse corporelle.

Conclusion La VJI se superpose à l'AC dans une plus grande mesure chez les patientes enceintes que chez les patientes non enceintes. Par conséquent, une approche par repère pour réaliser une cannulation de la VJI pourrait exposer les femmes enceintes à un risque plus élevé de ponction de la carotide. Cette étude a été enregistrée à www.clinicaltrials.gov (NCT T00464828).

The internal jugular vein (IJV) is the access site of choice for central vein cannulation because of its accessibility during surgery and its predictable anatomic location. Also, the area can be compressed easily in the event of bleeding complications. Generally, localization of the IJV is performed with the aid of anatomical landmarks and palpation of the carotid artery (CA).¹ However, there is a significant risk of complications associated with IJV cannulation, even in experienced hands. Puncture of the CA during central venous cannulation (CVC) has been reported to occur 2–19% of the time in adults.²

Although IJV cannulation is not a common procedure in pregnant women, it may be required for the management of high-risk and critically ill patients. The incidence of complications related to IJV cannulation in the obstetric population is unknown, but it may be higher than in non-pregnant patients due to difficulty in identifying landmarks secondary to changes in body habitus.³ It is unknown whether pregnancy affects the relative position of the IJV and CA. Recently, ultrasound has emerged as an alternative to the traditional methods of vessel localization for CVC.^{4,5} Ultrasound also allows the procedure to be simulated, thus facilitating the study of this procedure in pregnant patients, in whom there is a low frequency of CVC.

The primary objective of this study was to compare the success rate of IJV cannulation and the incidence of carotid puncture in pregnant and non-pregnant women using an ultrasound-simulated procedure. Additionally, we wanted to study the relative position of the IJV and CA in the neck in these two groups of women. This trial was registered at www.clinicaltrials.gov (NCT T00464828).

Methods

This study was approved by the Review Ethics Board at Mount Sinai Hospital, and written informed consent was obtained from all subjects. We recruited full-term pregnant women and non-pregnant female volunteers. Pregnant women who were either in early labour or scheduled for elective Cesarean delivery were recruited while being admitted to the labour and delivery floor. Non-pregnant female volunteers (i.e., no financial compensation), including hospital staff and in-patients, were recruited with the aid of signs posted in the hospital and in the surgical wards. We included women aged 18 to 40 yr and excluded those with visibly abnormal neck anatomy, previous surgery or trauma involving the neck, or prior cannulation of the neck vessels. Women were not matched by body habitus.

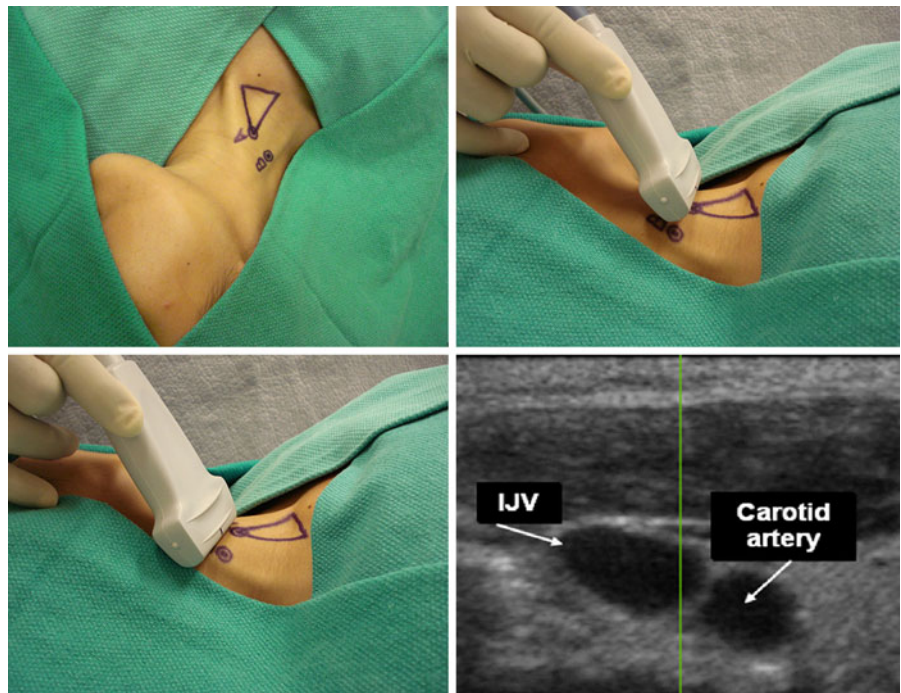
The subjects in each group were positioned supine on a gurney with a wedge under the right hip (if pregnant) and with their heads turned 35° to the left. We studied the two approaches commonly used to localize the IJV, i.e., the central landmark approach and the palpatory approach, as described below. The optimal needle insertion point for each approach was marked on the skin, and the central venous cannulation was simulated, as described in a previous study.⁶ The landmark approach was studied first in each group and in each subject, followed by the palpatory approach. The insertion points were marked by a single experienced investigator.

For the central landmark approach, the insertion point was defined as the apex of the triangle formed by the two heads of the sternocleidomastoid muscle as the sides of the triangle and the clavicle as the base.⁷ If the landmarks were not easily identifiable, they were accentuated by having the subject raise her head against resistance created by an investigator placing his/her hand on the subject's forehead. If the landmarks were still difficult to identify, the best estimate of the apex of the triangle was marked. The apex was marked as point A (Figure). An imaginary line representing the needle trajectory was drawn from this point towards the centre of the right hemithorax.

For the palpatory approach, the carotid pulse was felt half the distance along the medial border of the sternocleidomastoid muscle, and point B was marked just lateral to the pulse (Figure). An imaginary line representing the needle trajectory was drawn from this point toward the outer third of the clavicle.⁸ We did not use maneuvers that would increase the diameter of the neck vessels, such as a valsalva or breath-holding and head down position.

For the central landmark approach, the ease of assessing the landmarks was categorically scored for the groups on a scale of 0–2, with 0 = easily palpable; 1 = palpable with

Figure Upper left: Points A and B depict insertion points for central landmark approach and palpatory approach, respectively. Upper right and lower left: The centre of the ultrasound probe is positioned at an angle to mimic the needle direction in the central landmark and in the palpatory approach, respectively. Lower right: The built-in cursor coinciding with the centre of the probe is projected onto the screen and defines the outcome (internal jugular vein puncture, carotid artery puncture, or missed attempt)



the aid of a head lift against resistance; 2 = not palpable even against resistance.

Two-dimensional ultrasound images of each subject's neck were then obtained using a 15-10 MHz linear probe (MicroMaxx system, Sonosite Canada Inc, Markham, ON, Canada). Throughout the study, the same investigator (N.S.) placed the centre of the probe similarly on each subject's skin at the pre-marked insertion points within the same parasagittal plane so as to simulate the placement of a syringe and needle for central venous cannulation.⁶ The investigator was blinded to the image that was generated on the ultrasound screen at the time. The probe was applied to the skin with minimal pressure to limit neck vessel compression. Once the image quality was adequate, the built-in vertical cursor that delineates the path of a needle was placed in the image (Figure) by an unblinded investigator who determined the outcome of each attempt for both approaches and for both groups. If the cursor intersected the lumen of the IJV without intersecting the CA, the attempt was considered successful. If the CA was intersected, it was noted as a carotid puncture. If the beam intersected both the vein and the artery, it was also considered a carotid puncture. Otherwise, the simulated puncture was considered a missed attempt.

For the analysis of the relative position of the vessels in each approach, the unblinded investigator (N.S.) performing the ultrasound saved the best images at points A (landmark approach) and B (palpatory approach). Three investigators who were blinded to the patients' characteristics and the scoring of their co-investigators scored all ultrasound images independently. We used the scoring

system described by Troianos *et al.*⁹ The scoring was defined as follows: 0 = the IJV was completely lateral to the CA on the image display; 1 = $\leq 25\%$ overlap between the IJV and the CA; 2 = $>25\%$ and $\leq 50\%$ overlap between the IJV and the CA; 3 = $>50\%$ and $\leq 75\%$ overlap; and 4 = $>75\%$ overlap.

Sample size calculation

Using 80% power and a two-sided α of 0.05, the original study was designed to detect an absolute increase of 15% in the carotid puncture rate of pregnant women compared with non-pregnant women. Assuming a puncture rate of 19% in the general population,² 135 women per group were required. Therefore, we planned to recruit 150 women in each group to account for protocol violation, dropouts, and data contamination issues.

Statistical analysis

The Wilcoxon rank-sum test for two independent samples was used to compare continuous factors (e.g., age, body mass index [BMI]), and the Fisher's exact test was used to compare categorical factors between the two groups of women (e.g., IJV puncture and ease of palpation). No corrections for multiple comparisons were made. Since degree of overlap was recorded as an ordinal variable, the correlation between BMI and vessel overlap was studied using a polytomous logistic regression model. Polytomous logistic regression models the likelihood of being in a higher category on the ordinal scale as a function of the

independent variable (i.e., pregnant compared with non-pregnant).¹⁰ For all analyses, a $P < 0.05$ was considered as indicating a statistically significant difference. All the analysis were performed using SASTM version 9.01 (SAS Institute, Inc., Cary, NC, USA) statistical software.

Results

Following 12 months of recruitment, 173 patients were found to meet inclusion criteria, and 161 of them agreed to participate (99 pregnant women and 62 non-pregnant women). Despite concerted efforts, recruitment of non-pregnant volunteers was more difficult than expected. The trial would have required an estimated ten to 12 additional months to recruit 150 non-pregnant patients. Therefore, recruitment was halted after 161 patients, and analysis was conducted with this sample. The subjects in the pregnant group were older and heavier than the non-pregnant volunteers. The demographic data are shown in Table 1.

The identification of the landmarks was more difficult in the pregnant group than in the non-pregnant group (Table 2). The rates of successful IJV punctures, carotid punctures, and missed attempts did not differ significantly between the two groups of women (Table 3). The carotid puncture rate was only 3% higher in pregnant women using the palpatory approach (95% confidence interval [CI], -3.6%, 9.3%), and 10% higher using the central landmark approach (95% CI, -9.9%, 20.2%). The palpatory approach resulted in a significantly lower proportion of both carotid punctures and successful IJV punctures in both groups (Bowker’s test for symmetry: $S(3) = 31.71$; $P < 0.001$ for pregnant women and $S(3) = 15.27$; $P = 0.002$ for non-pregnant women).

The degree of IJV and CA overlap is shown in Table 4. In unadjusted analyses, there was more overlapping between the IJV and the CA in the pregnant women using both the central landmark approach ($P = 0.036$) and the palpatory approach ($P < 0.001$). To examine whether this overlap could have been confounded by BMI, we conducted a polytomous logistic regression modelling vessel overlap onto group status and BMI. After controlling for

Table 1 Demographic characteristics

	Pregnant (n = 99)	Non-pregnant (n = 62)
Age (yr)	33.0 (30.0, 65.0)	29.0 (27.0, 32.0)
Height (cm)	165.0 (158.4, 170.0)	163.0 (159.6, 169.0)
Weight (kg)	77.0 (67.0, 85.2)	62.0 (57.6, 72.5)
BMI (kg·m ⁻²)	27.7 (25.0, 31.2)	23.7 (21.1, 26.7)

Results are expressed as median (25th percentile, 75th percentile). BMI = body mass index

Table 2 Ease of identification of the anatomical landmarks required for internal jugular vein cannulation

Degree of difficulty	Pregnant (n = 99)	Non-pregnant (n = 62)	P value
0	43 (43.4%)	41 (66.1%)	0.012
1	53 (53.5%)	19 (30.6%)	
2	3 (3.0%)	2 (3.2%)	

0 = easily palpable; 1 = palpable with the aid of a head lift against resistance; 2 = not palpable even against resistance. Results are expressed as number of patients (%)

the effect of BMI, the difference between the groups remained significant in the palpatory approach, with the adjusted odds of being in a higher vessel overlap category among pregnant women being three times greater than the odds among non-pregnant women.

Discussion

Our results demonstrate that the identification of the anatomical landmarks is more difficult and the degree of overlap of IJV and CA is higher in pregnant women compared with non-pregnant women. However, in addition to the pregnancy proper, these results may be due in part to increases in BMI. Our study also demonstrates that the rate of anticipated successful IJV cannulation and carotid punctures does not differ significantly between pregnant and non-pregnant women regardless of the technique used.

There are many publications, including meta-analyses and structured reviews, attesting to the superiority of ultrasound-guided techniques over the surface landmark-guided techniques for CVC.¹¹ However, there is still limited use of ultrasound in current practice.¹² The results of our study support the use of real-time ultrasound for CVC in pregnant women. In this study, we used a similar model to that described by Bailey *et al.*, utilizing an ultrasound probe to simulate an actual syringe and needle scenario.⁶

There are many different methods of achieving CVC. A review of the literature suggests that the two most common techniques for IJV cannulation are the central landmark and the palpatory approach. English *et al.* first described the central landmark technique and reported a success rate of 93.5%. Subsequently, the same group reported a carotid puncture rate of < 1% with the same technique.⁷ Others, however, have reported a higher incidence of procedure failure and complications.^{A,13}

^A Dickson CS, Roth SM, Russell JM, *et al.* Percutaneous catheterization of the internal jugular vein central venous catheters:anatomic ultrasound assessment and literature review. Surgical Rounds 2006; 3: 102-7.

Table 3 Rate of internal jugular vein punctures, carotid punctures, and missed attempts in both techniques studied

	Pregnant (n = 99)	Non-pregnant (n = 62)	Difference in proportions (95% CI)	P value
Central Landmark Approach				0.241
IJV punctures	62 (62.6%)	45 (72.6%)	-10.0% (-24.6, 4.7)	
CA punctures	19 (19.2%)	6 (9.7 %)	9.5% (9.9, 20.2)	
Missed attempts	18 (18.2%)	11 (17.7%)	0.4% (-11.7, 12.6)	
Palpatory Approach				0.577
IJV punctures	35 (35.4%)	26 (41.9%)	-6.6% (-22.1, 8.9)	
CA punctures	6 (6.1%)	2 (3.2 %)	2.8% (-3.6, 9.3)	
Missed attempts	58 (58.6%)	34 (54.8%)	3.8% (-12.0, 19.5)	

IJV = internal jugular vein;
CA = carotid artery;
CI = confidence interval.
Results are expressed as number of patients (%)

Table 4 Degree of vessel overlap in both techniques studied

Overlap	Crude association			Analysis adjusted for BMI	
	Pregnant (n = 99)	Non-pregnant (n = 62)	P value	AOR pregnant vs non-pregnant (95% CI)	P value
Central Landmark					
None	7 (7.1%)	10 (16.1 %)	0.034	1.78 (0.98, 3.24)	0.060
≤ 25%	8 (8.1%)	8 (12.9 %)			
26-50%	34 (34.3%)	22 (35.5 %)			
51-75%	26 (26.3%)	10 (16.1 %)			
> 75%	24 (24.2%)	12 (19.4 %)			
Palpatory					
None	7 (7.1%)	13 (21.0%)	<0.001	3.03 (1.65, 5.56)	<0.001
≤ 25%	14 (14.1%)	13 (21.0%)			
26-50%	19 (19.2%)	18 (29.0%)			
51-75%	21 (21.2%)	7 (11.3%)			
> 75%	38 (38.4%)	11 (17.7%)			

* Score test for assumption of proportionality $P \geq 0.634$.
AOR = adjusted odds ratio;
CI = confidence interval;
BMI = body mass index.
Results are expressed as number of patients (%)

Our study did not demonstrate significantly different success rates of each individual technique in pregnant and non-pregnant women. The success rates for the central landmark approach in pregnant (63%) and non-pregnant women (73%) are lower than those reported in previous clinical studies describing this technique (range 80-100%).⁷ This difference may be due to the methods that were used to assess the study end points. In our study, we considered that only one attempt was made when the image was generated by the transducer positioned over the mark on the subject's skin. In clinical practice, many attempts in various directions may be made with one skin puncture, and it would still be considered a single attempt. However, our results are in keeping with another ultrasound simulation study in which success rates as low as 29% were documented with a single pass of the beam.^B Perhaps this speaks to the need for the utilization of real-time ultrasonography when performing IJV cannulation. It must be

recognized, however, that ultrasound simulation may or may not reflect the clinical experience accurately.

When comparing pregnant and non-pregnant women, the incidences of carotid punctures did not differ significantly for both the central landmark and the palpatory techniques. The 19% CA puncture rate using the central landmark approach is higher than that reported in the early papers (4%), but it is in the same range as that reported by Metz *et al.* when comparing 15 techniques for localization of the IJV using ultrasound simulation.⁵ In our opinion, there is an underestimation of CA punctures in the clinical setting, as many clinicians consider the puncture of the vessel with the locator needle insignificant, and they don't count it as an actual puncture. Clinical underreporting vs a thorough count using ultrasound may account for the difference between the original reports and this study's results.

Bailey *et al.* used ultrasound simulation in a general patient population.⁶ They simulated needle paths based on the central landmark approach for IJV cannulation. The simulated needle path missed the lumen of the internal

^B Legler D, Nugent M. Doppler localization of the internal jugular vein facilitates its cannulation. *Anesthesiology* 1983; 59: A179.

jugular vein in 34% of the subjects and traversed the CA in 26% of subjects. The difference between Bailey *et al.*'s results and our study can be explained by differences in method. We considered an attempt to be successful when the cursor of the ultrasound beam intersected any part of the lumen of the internal jugular vein, whereas Bailey *et al.* defined success as the intersection of the middle 80% of the lumen.

An important finding of our study relates to the overlap of the IJV and the CA in both pregnant and non-pregnant women. This important relationship has been determined using ultrasound in a previous study by Troianos *et al.*⁹ In an ultrasound-imaging plane positioned in the direction of a cannulating needle, they concluded that the IJV is not lateral to the CA in the majority of patients. Instead, they found that the IJV overlies > 75% of the carotid artery in 54% of patients, predisposing these patients to carotid puncture if the cannulating needle traverses the IJV. We also found significant vessel overlap, but the incidence and degree of overlap in our subjects seemed lower and less than those observed by Troianos *et al.* The differences between the two studies may be related to the patient's position and the degree of head tilt, two factors that are most important in the determination of procedure failure and complications.¹⁴ We controlled for these factors; however, Troianos *et al.* do not mention such details in the description of their methods.

We detected a trend in this study; compared with the central landmark approach, the palpatory approach was associated with a lower incidence of carotid puncture but also a much lower rate of success. Vein width has been described previously as being significantly greater when measured lower in the neck rather than higher,¹⁵ and this may explain the apparent increase in successful IJV punctures and CA punctures with the central landmark approach.

Our study has some limitations. First, it was a simulation of the clinical procedure using an ultrasound-generated needle track, which may not accurately reproduce the clinical scenario. Unlike a needle tip, where a larger area of visualization is available for localizing the puncture site, the transducer hid a small area (approximately 1 cm² of skin underneath it when it was placed on the subject's skin. This difference may have made placing the transducer less accurate than placing a needle. Second, we did not control the amount of pressure that we applied while placing the transducer on the subject's skin, and this may have resulted in distortion of the underlying anatomy. Third, our study was limited to assessment of the right side of the neck, because cannulation of the right IJV is often preferred to cannulation of the left.^{15,16} The anatomic relationship of the IJV to the CA differs between the right and the left¹⁷; therefore, our data may not be applicable to the cannulation

of the left IJV. Another limitation of our study was the difficulty in recruiting non-pregnant women, resulting in early recruitment termination and a reduction in statistical power. Given the initial assumptions (i.e., 19% puncture rate in the general population, 80% power, two-sided α of 0.05), 161 patients in a 3:2 ratio of pregnant to non-pregnant women, the study had sufficient power to detect a difference of 22%. However, we found, at most, a reduction of 10% in the IJV puncture rate for pregnant women using the central landmark approach and a reduction of 6.5% using the palpatory approach. Assuming these effect sizes were consistent, the study would have required 608 and 1,342 patients, respectively. That is, the study as it was originally powered would not have resulted in a significant finding of differences in primary outcome if the effect sizes remained the same.

In summary, contrary to our assumption, our study showed that pregnancy is not significantly associated with a lower incidence of successful ultrasound-simulated IJV punctures and a higher incidence of CA punctures and missed attempts. However, our finding of non-significance cannot be taken to indicate that the incidence of CA punctures is the same for pregnant and non-pregnant women. Using the palpatory approach, our findings indicate that the CA incidence could be up to 9% higher in pregnant women. Our results demonstrated that pregnancy is associated with greater difficulty in the palpation of the anatomical landmarks required for IJV cannulation and more overlap of the IJV and the CA. This might predispose these patients to accidental carotid punctures. Hence, the utilization of an ultrasound-guided technique is advocated.

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Conflicts of interest None declared.

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