Right Internal Jugular Ultrasound Measurements during the Respiratory Cycle in Children

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ABSTRACT

Background: Point of care ultrasound could be useful as a non-invasive objective measure of throughout the respiratory cycle.

Purpose: To determine the reliability of measurements of the right internal jugular vein (RIJV). **Methods:** We performed a prospective observation study of children aged 6–17 years. Using M-mode ultrasonography one centimeter cephalad from the clavicle, triplicate measurements were recorded during inhalation and exhalation with the head straight ahead and 45 degrees leftward.

Results: Among the 40 enrolled subjects, mean diameters ± standard deviations of the RIJV (cm) were: maximum inhalation with head straight ahead (0.53 ± 0.18), leftward (0.78 ± 0.22); maximum exhalation with head straight ahead (0.54 ± 0.19), leftward (0.79 ± 0.22). Intraclass correlation coefficients were all significant ($p<0.001$).

Conclusion: The RIJV diameter can be reliably measured during the respiratory cycle; measures are larger with head turned 45 degrees leftward.

Keywords: Jugular, m-mode, respiratory, ultrasonography

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INTRODUCTION

Ultrasonography is widely utilized as a non-invasive and radiation-free imaging modality for both diagnostic and therapeutic purposes. Following extensive development by specialists in radiology, ultrasound is now widely utilized by cardiologists, obstetricians, and emergency physicians.

Ultrasound has been used to study pulmonary disease and assist with critical care procedures in the pediatric emergency department. Investigators have evaluated the utility of various ultrasound findings such as B lines and air bronchograms in the diagnosis of pneumonia and bronchiolitis (1-5). Other investigators have assessed confirmation of endotracheal tube insertion (6, 7) and the success of internal jugular vein cannulation for central line placement using ultrasound.8

Quantitative measurements of vasculature have not been used to assess the respiratory cycle for children. Initially, we explored several candidate measures of the internal jugular vein, pleura, and diaphragm during the respiratory cycle. The right internal jugular vein (RIJV) was chosen as the optimal site with the most potential to find consistent quantifiable data by our multidisciplinary team. The purpose of this study was to determine the diameter of the RIJV in children with normal respiratory physiology during the respiratory cycle and to evaluate the reliability of those measurements. It was the goal of this study to establish normative values of the RIJV for healthy children during the respiratory cycle.

METHODS

We performed an exploratory, observational study at a tertiary care level I pediatric trauma center with an annual volume of approximately 60,000 patients per year. Subjects were children aged 6-17 years who presented to the Emergency Department from January 1, 2014 until January 1, 2015. Our study was approved by the affiliated university's Institutional Review Board. Our study is registered at on the Clinical Trials government website (NCT02004938).

Children were excluded from participation if they had a baseline chronic lung disorder (including asthma with an exacerbation in the past year), current respiratory illness, fever, Emergency Services Index (ESI) triage9 category of 1 or 2 (high acuity), chronic cough, dyspnea with exercise, wheezing, or a history of smoking by self and/or parent report. In addition, a co-existing acute pulmonary process (e.g. lobar pneumonia), and impending respiratory failure also excluded children from participation. Children were excluded if they had prior cardiac disease, significant musculoskeletal abnormalities (such as scoliosis) which the potential to compromise baseline pulmonary function testing, a history of smoking tobacco or marijuana use, allergy to ultrasound gel, or prematurity, defined as birth at less than 37 weeks gestation.

Prior to study commencement, 20 children were recruited to pilot study methods. In an attempt to find the best candidate measurements during the respiratory cycle, we evaluated the internal jugular vein, pleura and diaphragm. For quality assurance, a pediatric cardiologist, pediatric pulmonologist and the director of ultrasound medicine in the pediatric emergency department were available for pilot study testing, witnessed technique and reviewed stored ultrasound images. After deliberations as a study team, change in right internal jugular vein diameter during respiration was chosen as the best potential candidate measure. The first step in its evaluation was to determine reliability of the measurements.

After the pilot study testing was completed, 40 subjects were enrolled. A Modified Woods pulmonary index score10 and a Gorelick Dehydration Scale 11 were performed on each subject in an attempt to enter patients with normal respiratory physiology and euvolemia. Using bedside ultrasonography with a Sonosite Titan® ultrasound machine (Sonosite, Bothell, Washington, USA), each measurement was taken with the subject lying in bed with the head of the bed elevated at 45 degrees. A L38 linear probe was used throughout the study. The L-38 linear probe has a 10-5Hz range frequency and a 38mm aperture. The machine was set to 3.8cm depth, which was determined by the research team in pilot study testing. The ultrasound linear probe was placed at 1 cm cephalad to the right sterno-clavicular junction (Figure 1).

After identification of the RIJV in B mode, the ultrasound measurements were obtained in M mode. A scan line was projected through the anterior and posterior walls of the RIJV. Three measurements of the diameter of the RIJV at peak inhalation and peak exhalation during tidal breathing were recorded by the principal investigator (Figure 2) with the head of the subject in two positions: straight ahead and turned 45 degrees to the left. The maximum inhalations and exhalations were marked by the investigator while the right hand of the investigator was holding the probe in contact with the patient over the RIJV. Still and video ultrasound images of the RIJV were recorded throughout the study by the primary investigator.

Statistical analysis

Standard descriptive statistics were used to describe RIJV diameter. Reliability was assessed through calculations of intraclass correlation coefficients and 95% confidence intervals. The Pearson correlation coefficient was used to examine the relationship between age and internal jugular vein diameter. Analysis were performed using IBM © SPSS Statistics software, Version 21.0 (IBM, Armonk, NY, USA).

RESULTS

Sixty one patients were approached for enrollment following completion of the pilot study. Forty children participated in the study. Reasons for study exclusion included: patient refusal (6), no legal guardian present (5), history of asthma not initially documented in the chart (3), prematurity (2), language barrier (2), parent refusal (2), and respiratory illness (1).

Forty subjects and their legal guardians completed informed consent, fulfilled inclusion criteria and were enrolled in the study. Eighteen patients had an Emergency Severity Index (ESI) triage index of 3, 20 patients had an ESI triage index of 4, and 2 patients had an ESI triage index of 5. Discharge diagnoses included: musculoskeletal injury; motor vehicle accident; fall from standing height; facial injury; forehead laceration; and pharyngitis. All subjects had a modified clinical asthma scoring of 0 and a Gorelick dehydration scale of 0.

The mean age of the subjects was 11.8 years, [Interquartile range 9.25-14]; 45% (18) were female. Mean diameters and standard deviations of the RIJV in centimeters are listed in the Table, along with intraclass correlation coefficients (ICC). ICC measurements were obtained with the head straight as well as with the head rotated 45 degrees leftward. Peak inhalation and peak exhalation ICC were all significant ($p<0.001$). There were no differences when comparing RIJV diameter with peak inhalation directly with peak exhalation. There was no change in RIJV diameter with age ($r= 0.24$ for head in the neutral position ($p=0.14$), $r=-0.06$ for head rotated leftward ($p=0.69$)).

DISCUSSION

We found that the RIJV could be reliably measured during peak inhalation and peak exhalation in children in two different head positions: with the head straight ahead; and with the head rotated 45 degrees leftward. These findings support our objective to find reliable ultrasound measurements during the respiratory cycle.

Overall, the diameter of the RIJV was larger with the head rotated 45 degrees leftward when compared to the diameter of the RIJV with the head straight ahead. The reason for the contralateral head turn leftward was to facilitate contact between the skin and the probe (12). In prior studies, if the head is rotated, the RIJV has been found to be significantly larger when compared with the head straight ahead (13). This increase in RIJV diameter with head positioning may be due to the constricting effect of adjacent strap muscles (13, 14). We chose the RIJV after noticing consistent, clear quantifiable measurements throughout our pilot study testing. A comparison of left and right internal jugular vein diameters has suggested that the left internal jugular vein diameter measurements are more variable in comparison to the RIJV with increased intrathoracic pressure. This study also showed that the left internal jugular vein has consistently smaller cross sectional areas than the RIJV (15).

The diameter of the internal jugular vein in children increases during a Valsalva maneuver compared to tidal respiration.12,16 Although the pediatric literature is limited, there have been several adult studies suggesting that an increased peak inspiratory pressure hold, increased positive end-expiratory pressure, and increased tidal volume significantly increases the cross sectional area of the RIJV (15,17-19). This suggests that increased intrathoracic pressures or air-trapping in conditions such as acute asthma may result in an increased diameter of the RIJV in children with respiratory distress.

The bed positioning in prior studies which measured the diameters and cross sectional areas of the RIJV occurred with subjects lying flat12 or in Trendelenburg (15, 17-18). Our results are derived from a standardized position with the head of the bed elevated to 45 degrees. This was intentionally set to use in those with acute respiratory illness who may need nebulized medications in future studies. Further analysis with the head of the bed elevated to 45 degrees is needed with either Valsalva maneuver or acute respiratory illness to see the effect of bed positioning and RIJV diameter size.

In our attempts to establish a potential surrogate measure of pulmonary function, we did not find a significant relationship between RIJV diameter and age in children 6 to 17 years of age. In anticipation for further studies including those with respiratory symptoms and the use of incentive spirometry, we chose to enroll children ages 6 years and older. Prior studies support our findings that there is no correlation between RIJV diameter size among those 6 years of age and older during a normal respiratory cycle (12, 20).

Although we did not enroll those less than 6 years of age, a review of the literature suggests a correlation between age and internal jugular vein diameter in subjects less than 6 years of age, possibly due to the elasticity of the internal jugular vein (12, 16). As this measurement is further explored through additional studies, expansion of age criteria may also be necessary to see RIJV diameter size and age across all ages.

With the refinement of technique in our pilot study, the RIJV was best visualized without overlap from the right carotid artery at 1 cm cephalad to the clavicle. It appeared that scanning more than 1 cm cephalad resulted in overlap of the carotid artery with the RIJV, making a tracing in M mode of the anterior and posterior wall of the RIJV more difficult to obtain. Prior literature has shown overlap of the RIJV and the carotid artery at 2 cm or more cephalad from the clavicle when attempting to establish cannulation of the RIJV vein in the Trendelenburg position (8). Even though our measurements were not collected with the subjects in Trendelenburg position, our results support that a more caudal measurement location may lessen the chance of overlap of the RIJV and carotid artery.

Our study represents an important preliminary step in the exploration of bedside ultrasonography for assessing the respiratory system. We have demonstrated that the RIJV can be reliably measured in children with the head of the bed at 45 degrees and that it does not vary in size with the respiratory cycle in children without respiratory distress.

The ultimate goal of our ongoing research is to define a reliable and accurate measure of pulmonary function in children for use in the evaluation and management of common respiratory illnesses such as asthma. We believe that point of care ultrasound should be further explored as a surrogate measure of pulmonary function. Evaluation of RIJV diameter variation during the respiratory cycle in children experiencing an asthma exacerbation and the correlation of diameter to pulmonary function should be included in future studies.

Limitations

Our study had a number of limitations. Small variations in the size of the RIJV during respiration may not have been detectable. The ultrasound unit utilized in this study did not allow simultaneous B- and M-Mode visualization of the RIJV. This could have caused small measurement inaccuracy resulting from minor misalignment of the M-Mode beam from the widest vessel diameter. Although our study team consisted of experts in ultrasonography who reviewed primary investigator scans for quality assurance during the pilot study, only one investigator obtained measurements. Inter-rater reliability of RIJV measurements among scanners with a spectrum of experience in ultrasonography should be established in future work.

CONCLUSION

the right internal jugular vein diameter can be reliably measured in children 6 to 17 years of age with both the head positioned in the midline and with rotation 45 degrees leftward. The diameter of the RIJV is larger with the head turned 45 degrees leftward. Future studies should include examination of the RIJV diameter and variation during the respiratory cycle among children with respiratory distress to determine if this ultrasound measurement can be used as a surrogate marker for pulmonary function.

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Table: Quantitative analysis of the right internal jugular vein at maximum inhalation and maximum exhalation.

Head Position/Respiratory Phase	**Mean IJ diameter ± Standard Deviation (cm)**	**Intraclass Correlation Coefficient (ICC)**	**95% CI**

Straight Ahead/Inhalation	0.53 ± 0.18	0.87	0.79, 0.92
Straight Ahead/Exhalation	0.54 ± 0.19	0.83	0.73, 0.90
45 Degrees/Inhalation	0.78 ± 0.22	0.90	0.83, 0.94
45 Degrees/Exhalation	0.79 ± 0.22	0.89	0.82, 0.93

Mean diameter, standard deviations and intraclass correlation coefficients of the right internal jugular vein at maximum inhalation and maximum exhalation

Fig. 1: Technique for right internal jugular vein ultrasound for study analysis.

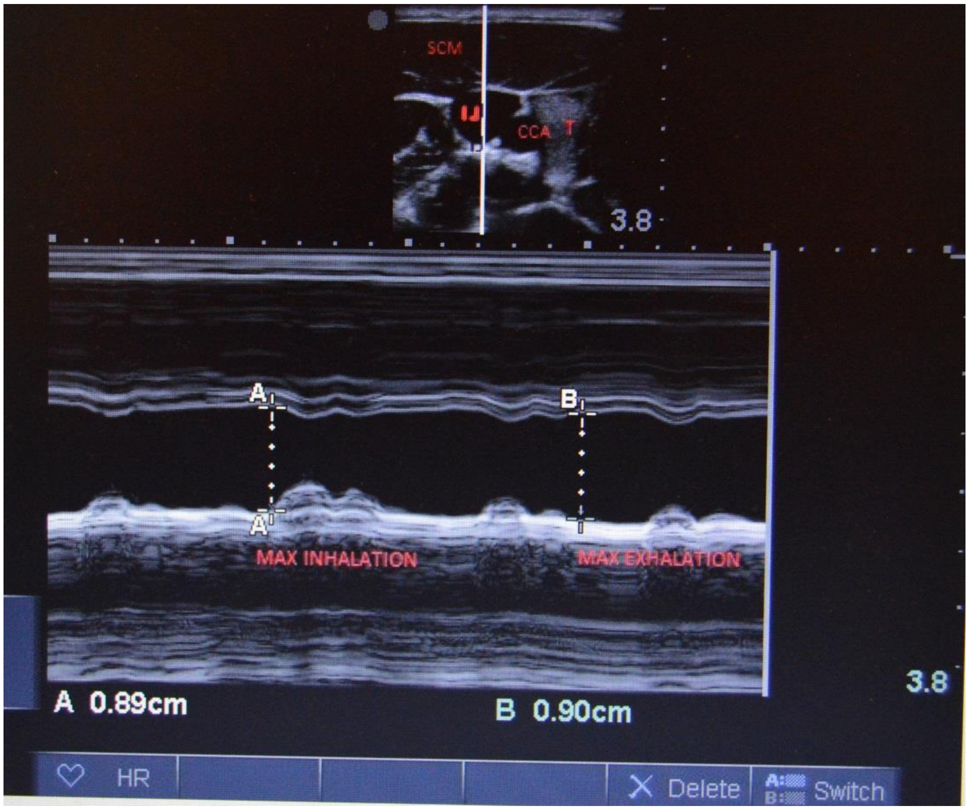

Fig. 2: Ultrasound measurements of right internal jugular vein in M Mode (in cross section and corresponding M-mode tracing).
IJ = right internal jugular vein
CCA = common carotid artery
T = thyroid
SCM = sternocleidomastoid
A = M mode tracing measurement at maximum inhalation
B = M mode tracing measurement at maximum exhalation