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Case Report

New acoustic window for assessing the inferior vena cava collapsibility in humans in the prone position

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Abstract

Objective: Ultrasound assessment of inferior vena cava (IVC) collapsibility is performed to determine the volume status of critically ill patients. We propose a new acoustic window for visualizing a vein in a prone patient.

Case Presentation: A healthy volunteer took part in the study. The study protocol includes two stages: 1) performing a magnetic resonance imaging (MRI) examination to determine the projection of a certain IVC area on the posterior chest surface (holotopy), 2) performing an ultrasound scanning in the area of IVC projection in order to identify it and determine its dimensions.

Conclusion: The 11th intercostal space parallel to the paraspinal line allows to visualize the IVC in the prone position. This gives a potential opportunity to use it to assess the IVC collapsibility. Its potential advantage is the ability to assess the compressibility of IVC in the antero-posterior direction.

Keywords: Ultrasound, Hemodynamics, Volume status, Monitoring, Point-of-care

Introduction

Ultrasound assessment of inferior vena cava (IVC) collapsibility is performed to determine the volume status of spontaneously breathing and not mechanically ventilated critically ill patients. Conventional assessment is performed in patients in the supine position (1-5). In this case, a low-frequency ultrasound probe is placed over the subxiphoid area to visualize IVC where it enters the right atrium in a longitudinal section in B-mode. Subsequently the IVC diameter is measured 2 cm caudal to the hepatic vein-IVC junction. Then, changes in the anterior-posterior IVC dimension are recorded in M-mode over 3 respiratory cycles, the maximum and minimum vein dimensions are determined, the collapsibility index (CI) is calculated, and hypovolemia is detected if the IVC IC is more than 50%. However, this method cannot be used with patients in the prone position, as subxiphoid area cannot be accessed. The fact is that the prone position is used in intensive care, particularly in patients with acute respiratory distress syndrome, to improve oxygenation (6). Early prone-to-supine position change can worsen the patient's condition, in particular, worsen oxygenation and raise the possibility of hypoxic injury to the internal organs and the brain. Therefore, in the interests of the patient, prone position may be used for a duration of 16-24 hours per session (7). Hensley and Wang (8) proposed a technique for assessing the patient's volume status in the prone position. The ultrasound probe is placed at the patient's right upper abdomen mid axillary line. Then the IVC is visualized at the junction with hepatic vein in B-mode, and subsequent measurements of the lateral-medial IVC dimension are performed in M-mode. Since this technique does not involve measuring the anterior-posterior dimensions of IVC, it can be less accurate than the conventional one. The fact is that the compressibility of veins, including IVC, in the antero-posterior direction differs from that of the lateral-medial direction (9). Thus, the possibility of assessing a patient's volume status in the prone position based on measurements of the anterior-posterior dimensions of IVC may be of scientific and applied interest.

Case Presentation

A 26-year-old male healthy volunteer with body mass of 75 kg (body mass index, 22.2 kg/m^2) took part in the study. The study protocol includes two stages: 1) performing a magnetic resonance imaging (MRI) examination to determine the projection of a certain IVC area on the posterior chest surface (holotopy), 2) performing an ultrasound scanning in the area of IVC projection in order to identify it and determine its dimensions. The MRI examination was performed on a Siemens Magnetom Symphony 1.5 T MRI machine (Germany). An ultrasonic scanner Mindray TE7 with ultrasonic transducer model C5-2s (China) was used for ultrasound examination. MRI images in coronal, axial and sagittal plane were acquired to determine IVC holotopy. During the analysis of MRI images, it was found that the IVC area, which was 2 cm caudal to its junction, with hepatic vein was projected onto the posterior chest surface at the 11th intercostal space along the right paraspinal line (Figure 1).

The distance from the surface of the chest to the IVC was also established, which was 11 cm. Then an ultrasound examination was performed. For this purpose, a 2-5 MHz ultrasonic convex transducer was placed on the right side over the 11th intercostal space parallel to the paraspinal line on the body of the healthy volunteer who was lying horizontally on his front. Using B-scanning mode, the IVC area of interest was identified at a depth of 11 cm (Figure 2).

The IVC was identified by ultrasound. The presence of blood flow was confirmed in CF-mode. Then, in M-mode, the changes in the anterior-posterior IVC size were recorded over 3 respiratory cycles, and the maximum and minimum dimensions of the vein were determined, which were 9.0 and 6.4 mm, respectively (Figure 3).

Using the obtained values we calculated the IVC-CI, which was 38%. Then the obtained values were compared with the data acquired with the conventional technique (supine position). It turned out that the IC value calculated in a healthy volunteer in the prone position was comparable to the index value obtained in the supine position (IVC-CI = 42%). The authors certify that they obtained the appropriate consent form. The patient gave consent to the use of images and other clinical information to be reported in the article. The patient was assured that his name and initials will not be published and due efforts will be made to conceal his identity, but anonymity cannot be guaranteed.

Discussion

Ultrasound point-of-care allows to obtain important data that complement the results of other clinical, instrumental and laboratory data to determine the volume status of critically ill patients (10). For ultrasound examinations, standard acoustic windows are used. One of the objects of the study is the IVC. Hypovolemia is detected if the IVC IC is more than 50%. Traditionally, to visualize IVC, ultrasound probe is placed over the subxiphoid area (2-5). Changes in the anterior-posterior IVC dimension is used to calculate the IC. The use of this technique is possible when placing the patient on supine position. In the prone position, the traditional acoustic window

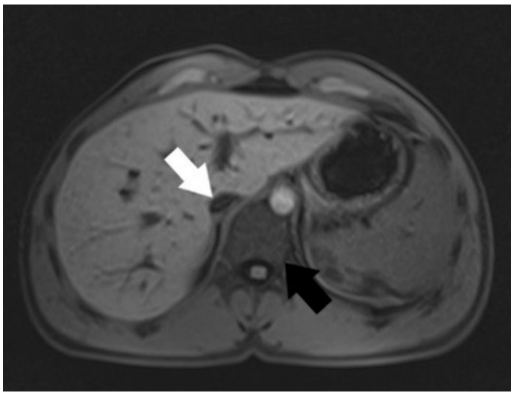

Figure 1. Axial fat-suppression T1-weighted image IVC images in a 26-year old man: IVC (white arrow) caudal to the hepatic vein-IVC junction, 12th thoracic vertebra (black arrow)

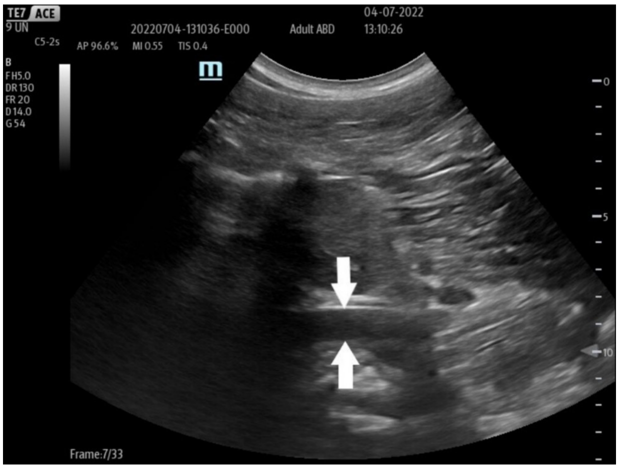

Figure 2. IVC ultrasound image with convex transducer (IVC indicated by arrows): B-mode ultrasound

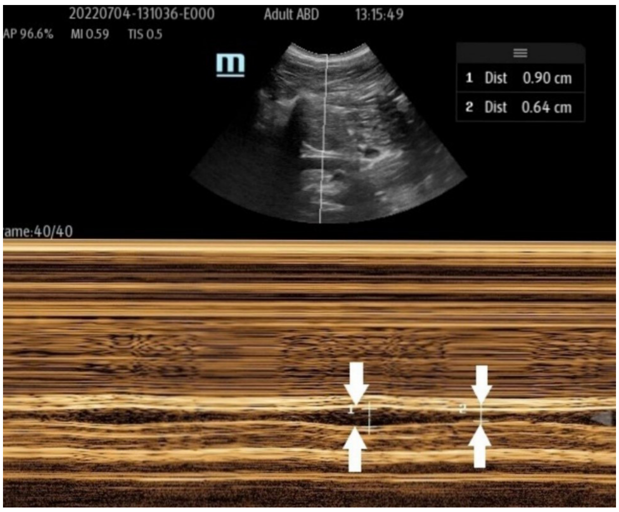

Figure 3. IVC ultrasound image with convex transducer (IVC indicated by arrows): M-mode ultrasound

becomes inaccessible for the installation of an ultrasound probe. In this regard, for a long time non-invasive IVC collapsibility monitoring in prone patients was not used. In recent years, the length of stay for critical patients in the prone position has increased significantly (7). This contributed to the development of new methods such as ultrasound point-of-care to determine the volume status of critically ill patients. For the first time, Hensley and Wang (8) proposed acoustic window as a technique to assess IVC collapsibility in the prone position. This technique involves placing an ultrasound probe at the patient's right upper abdomen mid axillary line. But this technique can be less accurate than the conventional one, since involve measuring the of the lateral-medial IVC dimension. Hedman et al (9) found that IVC collapsibility in the antero-posterior direction differs from that of the lateral-medial direction, which can lead to erroneous IVC-CI calculations. We have proposed the acoustic window as a technique for IVC visualization in prone position which allows us to assess the IVC collapsibility in the antero-posterior direction. The placing of an ultrasound probe in the 11th intercostal space parallel to the paraspinal line allows to visualize the IVC along the long axis. This possibility was demonstrated by only one case, which, on the one hand, limits the value of observation, but, sheds light on further research. The new acoustic window is located in the intercostal space. In some clinical cases, this may limit the IVC visualization when using a convex probe. However, the use of a phased array probe may offset these limitations.

Conclusion

Our case demonstrates that the new acoustic window allows to visualize the IVC in human in the prone position. This gives a potential opportunity to assess the IVC collapsibility. Its potential advantage is the ability to assess the compressibility of IVC in the antero-posterior direction. Further study of a larger patient population could demonstrate the utility of this technique in assessing the volume status of critically ill patients in a prone position.

Authors' Contribution

Conceptualization: Anton Kasatkin, Aleksandr Urakov.
Investigation: Ivan Zlobin.
Methodology: Anton Kasatkin.
Validation: Vadim Matreshkin, Ivan Zlobin.
Writing – original draft: Anton Kasatkin, Vadim Matreshkin.
Writing – review & editing: Aleksandr Urakov, Aleksei Shchegolev.

Competing Interests

None.

Ethical Approval

Informed consent was obtained from the volunteer for the publication of this report.

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