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Ultrasonography in the diagnosis and monitoring of intra-abdominal hypertension and abdominal compartment syndrome

Ultrasonografia a nadciśnienie wewnątrzbrzusne i zespół przedziału brzuszego

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Streszczenie

Despite their considerable clinical significance, intra-abdominal hypertension and abdominal compartment syndrome are rarely discussed in the context of ultrasonography. They occur in critically ill patients, usually hospitalized in intensive care units. Early diagnosis of these conditions is of key importance for prognosis as it allows for proper treatment and prevents high mortality. Although there are various methods for the assessment of intra-abdominal pressure, a measurement using a sensor-equipped catheter placed in the bladder is the gold standard. However, this technique does not allow to identify the etiology of the problem, which is usually resolved by analyzing patient's clinical data supported by imaging findings. Computed tomography is most often used for this purpose. Recent years have proved that point-of-care ultrasonography is also useful in this respect. This issue has become the basis for developing this review paper, which describes the opinion of the experts of the World Society of the Abdominal Compartment Syndrome on the nomenclature, classification and diagnosis of intra-abdominal hypertension. We also presented preliminary data on the role of ultrasound in the diagnosis and monitoring of intra-abdominal hypertension and the contribution of this modality to the choice of appropriate treatment for patients presenting with this clinical condition. A multi-center study used point-of-care ultrasonography to assess the position of a g-tube in the stomach and its contents, intraluminal content status and bowel motor function, the monitoring of gastric drainage and forced intestinal evacuation, the presence of ascites and ascitic status without and after paracentesis. Even when simplified, the method was found to be very useful.

Definition and classification

Intra-abdominal hypertension (IAH) and abdominal compartment syndrome are terms referring to the same condition, which only differs in its severity. This nomenclature is recommended by the World Society of the Abdominal

Compartment Syndrome (WSACS)⁽¹⁾. Intra-abdominal hypertension specifically refers to IAH between 12 mmHg and 20 mmHg, whereas ACS refers to intra-abdominal pressure >20 mmHg with associated one new organ dysfunction.

Furthermore, four stages of IAH have been distinguished:

- stage I, 12–15 mmHg;
- stage II, 16–20 mmHg;
- stage III, 21–24 mmHg;
- stage IV, >25 mmHg.

This staging is associated with an increasing decrease in perfusion, mainly in the kidneys and the intestines, which leads to organ ischemia due to restricted venous outflow from important abdominal organs. ACS in critically ill patients is associated with high mortality rates. Untreated ACS leads to death in more than 90% of patients as compared to 25–75% for treated ACS and 16–37% after surgical decompression⁽²⁾. Early detection is crucial in this situation. This type of pathology is mainly dealt with by surgeons and intensive care physicians. Other specialists, including imaging diagnosticians, usually have limited knowledge on this issue. According to WSACS, it is worth familiarizing with the following data:

- normal intra-abdominal pressure (IAP) is 5–7 mmHg during critical illness;
- increased IAP is defined as IAP >12 mmHg;
- primary IAH or ACS is due to an injury or disease in the abdomino-pelvic region;
- secondary IAH or ACS is a consequence of extra-abdominal pathology;
- recurrent IAH or ACS refers to the condition which redevelops following previous IAP normalization;
- abdominal perfusion pressure (APP) = mean arterial pressure – intra-abdominal pressure; APP is <60 mmHg in ACS;
- polycompartment syndrome refers to hypertension in at least two abdominal compartments;
- abdominal compliance is a measure of the ease of abdominal expansion (elasticity), which is determined by the elasticity of the abdominal wall and diaphragm; it is expressed as a change in intra-abdominal volume per change in IAP;
- lateralization of the abdominal wall is the phenomenon where the abdominal wall (rectus abdominis muscles in particular) moves laterally away from the midline in cases of treatment using open abdomen techniques.

Pathogenic factors

The World Society of the Abdominal Compartment Syndrome has distinguished the following pathogenetic factors:

1. Diminished abdominal compliance – abdominal surgeries, major injuries, major burns, prone positioning.
2. Increased intraluminal contents – gastroparesis, major gastric retention, bowel obstruction, colonic pseudo-obstruction, volvulus.
3. Increased intra-abdominal contents – acute pancreatitis, meteorism, ascites, pneumoperitoneum, hemo-peritoneum, abdominal collections, abscess/extensive

inflammation, intra- and extraperitoneal tumors, laparoscopy, liver failure or cirrhosis with ascites, peritoneal dialysis.

4. Capillary leak – massive fluid resuscitation, acidosis, damage due to follow-up laparotomy, hyperthermia, multiple blood transfusions.
5. Other: age, bacteremia, coagulopathy, increased pillow angle during sleep, surgical treatment of large abdominal hernias, mechanical ventilation, obesity or overweight, peritonitis, pneumonia, sepsis, shock, and hypotension. Some authors also mention ruptured abdominal aortic aneurysm and pregnancy⁽²⁾.

Diagnosis

Vesical intra-abdominal pressure measurement performed in a patient in the supine position is the gold standard. This parameter may be also measured in the stomach or large bowel. These methods are invasive and may cause complications. Therefore, different methods for the measurement of intra-abdominal pressure based on the assessment of abdominal wall tension have emerged^(3–5). So far, these methods have not been approved by WSACS. According to these experts, vesical intra-abdominal pressure measurement remains the gold standard. IAP should be monitored at 4–6-hour intervals (or continuously in some cases) to monitor the efficacy of the treatment used and decide for surgical intervention in the case of persisting high IAP. Decompression, which involves creating the so-called open abdomen, may be performed. Pressure monitoring itself does not reflect the intra-abdominal situation or the etiology of IAH/ACS. Therefore, CT is performed in some cases^(6–8). In this modality, the following symptoms are suggestive of this pathology: bell-shaped abdomen, the ratio of antero-posterior-to-transverse abdominal diameter >0.80, the ratio of anteroposterior-to-transverse peritoneum parietale diameter >0.52, slit-like inferior vena cava and renal veins, thickened and strongly contrast-enhancing bowel and gastric walls.

Intra-abdominal hypertension and ultrasonography

Patel *et al.*⁽⁷⁾ found reduced end-diastolic flow and even its reversal in the hepatic and renal arteries in a few sonographically assessed patients. WSACS experts proposed a four-step algorithm for the management of patients with IAH/ACS in their guidelines⁽¹⁾. Abdominal ultrasound to reveal space occupying lesions is recommended only in the initial step. A study on the role of point-of-care ultrasound (POCUS) in the management of patients with IAH conducted by a group of international experts was published in 2017⁽⁹⁾. Ultrasound was performed using a 3.5 MHz convex transducer applied at six positions. The transducer was placed in the epigastric fossa, which allowed to additionally evaluate gastric content status, to ensure the correct

position of the introduced g-tube. Transducer was then placed in the peri-umbilical region and lower abdominal quadrants to assess the intestines. Bilateral subdiaphragmatic and suprapubic views were used to search for fluid collections. POCUS was performed at 6-hour intervals, immediately after IAP measurement. Furthermore, ultrasound-guided paracentesis was performed if needed. This way, POCUS assessed g-tube position in the stomach, its contents, intraluminal content status and bowel motor function. Gastric drainage, forced bowel evacuation, the presence of ascites and ascitic status without and after paracentesis were additionally monitored. Additionally, cardiac echo was performed and blood flow was assessed in the hepatic artery, renal arteries and the portal system in the initial stage of follow-up. The second stage of POCUS involved an evaluation of intraluminal contents and bowel motor function to decide about bowel evacuation and assess the inferior vena cava. Ultrasound-guided paracentesis was performed if needed. The third stage involved monitoring of ascites. According to the authors, POCUS was useful in the first three steps in the algorithm for the management of patients with IAH/ACS and is a good additional diagnostic tool to help make proper therapeutic decisions for critically ill patients.

However, it should be stipulated that the measurement of the width of the IVC will always fail in obese patients who usually present with some degree of IVC compression. This symptom may be also misinterpreted as hypovolemia.

Looking at the above mentioned causes of IAH/ACS, it may be concluded that most of them are acute conditions requiring emergency specialist intervention. Candan *et al.*⁽¹⁰⁾ published a study assessing the degree of correlation between IAH and increased renal arterial resistive index (RI). Increased RI was found in 53 (66%) out of 80 IAH patients, mainly in those with diabetes. The conclusions emphasized the importance of this symptom for the diagnosis of IAH. It should be noted, however, that elevated RI is common in diabetic nephropathy and not necessarily related to IAH^(11–13). This effect is observed in many other conditions that cause kidney dysfunction, also after kidney transplantation and extracorporeal shock wave lithotripsy (ESWL) used in the treatment of kidney stones^(14,15). However, IAH may develop gradually, e.g. in pregnancy, multiple pregnancy in particular. A similar effect occurs even more slowly with growing weight and decreasing compliance of integumental

muscles for compensating intra-abdominal hypertension. Non-compliant abdominal wall will be an additional factor promoting IAH in such cases. Here, the abdominal organs are tightly packed like things in an overfilled suitcase, which is referred to as the overfilled suitcase symptom. The appearance of the contents of such a 'suitcase' after its opening is a known issue. The effect of overfilled suitcase is long-term in obese patients with IAH. The softest structures, such as bowels, stomach and veins become compressed. For this reason, for example, a small amount of intestinal gas or a low bladder capacity may be found in individuals with significantly increased body weight. In patients with pelvic lipomatosis, not only the bladder, but also the ureters, rectum and veins in this region are compressed^(16,17). Obesity is also a known factor promoting reflux disease, esophageal hiatal hernia or even dysphagia^(18,19). Visceral fat distribution also often leads to hernias at less resistant sites in the abdominal integuments. Here, the viscera that are pushed out act like a safety valve, which modulates IAH to some extent. Since these patients have no spatial reserves, recurrences are often seen after tension repair of inguinal hernias. Higher intra-abdominal pressure in obese patients compared to normal-weight individuals was reported by Sugerman *et al.*⁽²⁰⁾ and Wilson *et al.*⁽²¹⁾, as opposed to Chena *et al.*⁽⁵⁾ It seems that the absence of IAH in some of obese patients may be explained by overstretching and thinning of the abdominal wall. In such cases, the integumental muscles lack the ability to shrink and act like stretched rubber. Therefore, these patients do not present with the symptoms of IAH. However, the spine loses an important stabilizing factor, i.e. efficiently functioning muscle corset of the abdominal wall, in such cases. High position of the diaphragm, which reduces the vital capacity of the lungs, is another negative factor in obese individuals.

The presented data show that point-of-care ultrasonography (POCUS) deserves a wider application in the diagnosis and monitoring of critically ill patients with suspected IAH. This technique should be also used in paracentesis.

Conflict of interest

The authors do not report any financial or personal connections with other persons or organizations, which might negatively affect the contents of this publication and/or claim authorship rights to this publication.

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