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Technique of ultrasonic detection and mapping of abdominal wall adhesions

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Summary. A technique for noninvasive ultrasound examination to detect and map abdominal wall adhesions is described. The examination is based on the demonstration of movement of abdominal viscera during real-time imaging. This movement is called viscera slide and either occurs spontaneously as a result of respiratory movement or may be induced by manual compression. Abdominal wall adhesions produce a restriction of viscera slide. Ultrasonic demonstration of restricted viscera slide has been used for the precise localization and mapping of abdominal wall adhesions prior to abdominal surgery. The technique may be particularly useful in providing safe initial access in patients undergoing laparoscopy who are at increased risk for trocar injury of viscera due to abdominal wall adhesions resulting from previous surgery or peritonitis.

Key words: Ultrasound – Detection of adhesions – Laparoscopy – Abdominal surgery

Surgeons planning the site of entry prior to laparoscopy or laparotomy must consider the presence and distribution of abdominal wall adhesions in patients who have previously undergone abdominal surgery. The reason for such a consideration relates to two potential problems that could occur during operations on patients exhibiting adhesions: (1) injury to the bowel or other viscera whose adherence to the abdominal wall is not recognized at the site of entry and (2) interposition of adhesions between the site of entry and the region of operative interest, in which case lysis of adhesions would be necessary.

We have previously described an ultrasound finding that can identify abdominal wall adhesions prior to abdominal surgery [1]. By the performance of an abdominal ultrasound examination prior to abdominal surgery, adhesions between the abdominal viscera and the abdominal wall may be discovered and their distribution, identified. Discovery of adhesions at a contemplated site of operative entry is important in avoiding inadvertent puncture of viscera by the introduction of the first trocar during laparoscopy, which is usually blindly inserted. Mapping of areas of adhesions to the abdominal wall may further guide the placement of trocars such that the most adhesion-free and, consequently, the quickest and safest approach to the area of interest may be planned.

The finding that identifies abdominal wall adhesions is based on the presence or restriction of ultrasonically observed movement of abdominal viscera in reference to the anterior abdominal wall. We call this movement viscera slide. Viscera slide either occurs spontaneously as a result of respiratory movement or may be induced by manual ballottement (Fig. 1 A). Adhesions between the abdominal contents and the anterior abdominal wall tether the viscera to the wall, resulting in viscera slide restriction (Fig. 1 B). During longitudinal ultrasound scanning, we have observed normal spontaneous viscera slide (produced by respiratory movement) ranging from 2 to ≥ 5 cm in distance. During either longitudinal or transverse scanning, we have noted normal induced viscera slide (produced by manual compression) of >1 cm in distance. In our preliminary report, we defined restricted viscera slide as being an ultrasonically detected reduction in viscera slide excursion of <1 cm for both spontaneous and induced viscera slide [1].

Further application of ultrasonic assessment of viscera slide as a means of detection has prompted us to develop a process for mapping and recording the regions beneath the abdominal wall that demonstrate restricted viscera slide and, hence, areas in which abdominal wall adhesions are likely to be present. The present report describes our technique of ultrasonic detection and mapping of abdominal wall adhesions and provides a convenient guide for the insertion of laparoscopy trocars and the placement of laparotomy incisions.

Patients and methods

The ultrasound examination is performed with the patient in the supine position. A real-time 5- or 7.5-MHz ultrasound scanning system is used.

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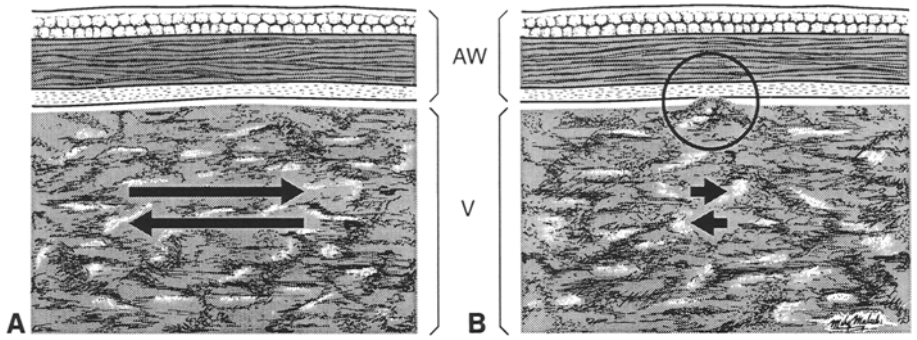

Fig. 1 A, B. Schematic drawing of viscera slide (*AW* abdominal wall, *V* viscera). **A** Normal viscera slide showing a wide excursion (*long arrows*) of the viscera. **B** Restricted viscera slide caused by an adhesion to the abdominal wall (*within circle*) that is characterized by a shorter excursion of viscera (*short arrows*)

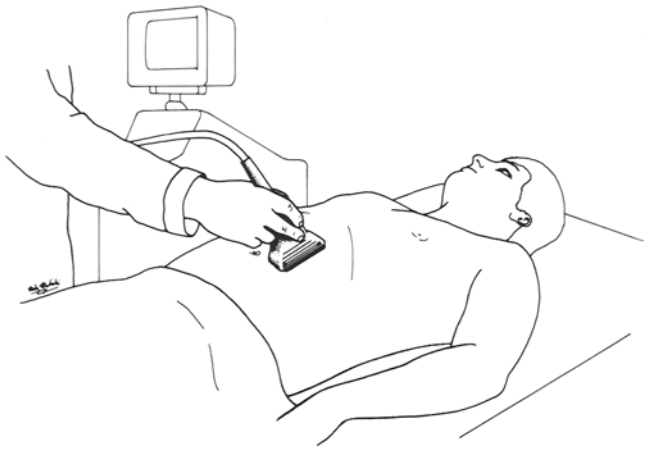

Fig. 2. Scanning technique used to detect viscera slide. The transducer is applied to the anterior wall. In this drawing, the linear axis of the linear-array transducer is vertical in respect to the subject, resulting in a longitudinal scan

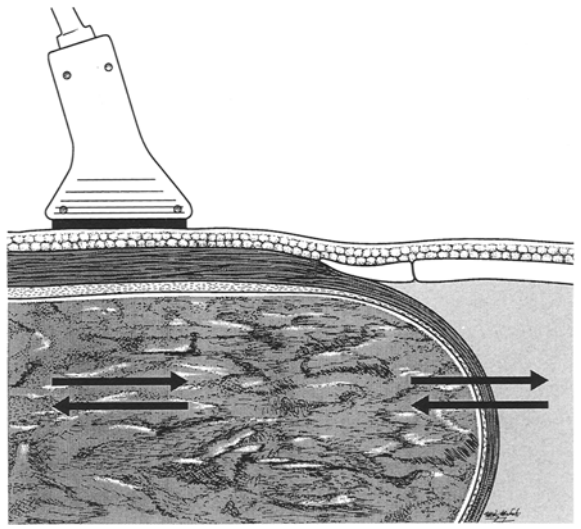

Fig. 3. Schematic drawing of spontaneous viscera slide. Respiratory movement of the diaphragm (*right arrows*) produces a viscera slide (*left arrows*) beneath the transducer on the abdominal wall

It is preferable to employ a linear-array transducer because such a transducer provides the longest field of view (footprint) of the tissue at the area of contact with the transducer. The assessment of viscera slide is made first by placing the transducer along a longitudinal scan path at a region of interest on the abdominal wall (Fig. 2). Acoustic coupling is achieved by depositing methyl cellulose gel between the skin and the

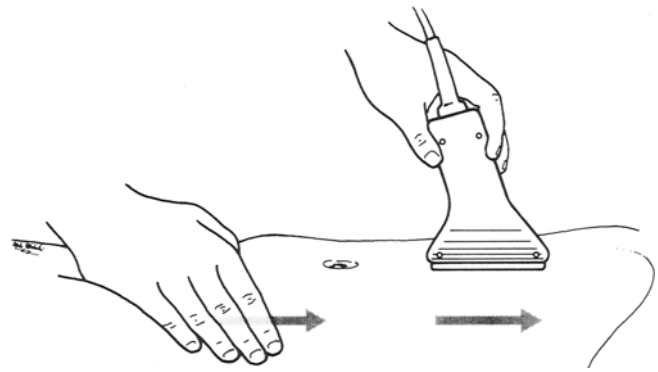

Fig. 4. Manual compression (*left arrow*) of the abdominal wall produces induced viscera slide (*right arrow*) beneath the transducer. The direction of the compressive force lies along the scan path of the transducer (linear axis of the transducer)

transducer contact surface. Ultrasound scanning is begun by observing the junction between the abdominal wall and the abdominal contents. This junction is usually readily identified by the juxtaposition of a stationary layered image of the abdominal wall and the less regular appearance of the abdominal viscera, which slides horizontally immediately deep to the abdominal wall as a result of respiratory movement. We refer to the ultrasonically detected movement that results from respiratory action as spontaneous viscera slide (Fig. 3), in distinction to induced viscera slide, which is produced by the force of manual ballottement (Fig. 4).

The most precise way to measure viscera slide is to observe the movement of the viscera on the ultrasound monitor during several respirations and to identify a persistent focal area at or near the surface of the moving viscera. Such a focal area is selected on the basis of a recognizable cluster of high- and low-intensity structures that move together through several respiratory cycles. The extent of the horizontal excursion is noted by measuring the distance traversed by the focal area. We define the excursion distance as being the maximal distance (in centimeters) traversed by a focal area during ultrasonic scanning as the focal area moves within the scan plane of the transducer. An electronic scale or calipers indicating horizontal distances should be available on the ultrasound instrument and should appear on the ultrasound monitor displaying the real-time image. This scale enables the ultrasonographer to measure the horizontal distance traversed by viscera beneath the transducer in a more precise manner (Fig. 5).

The ultrasound examination is performed in two phases: the detection and the mapping of restricted viscera slide. Detection is the recognition of restricted viscera slide. Restricted viscera slide is characterized by abnormally short movements of the abdominal contents immediately deep to the abdominal wall in response to spontaneous (respiratory motion) and induced (manual compression) forces. During longitudinal scanning, normal spontaneous viscera slide ranges in distance from 2 to ≥ 5 cm (Fig. 6 A, B). During both longitudinal and transverse scanning, induced viscera slide produced by manual compression (equivalent to the force used in a normal physical examination) exceeds 1 cm. Con-

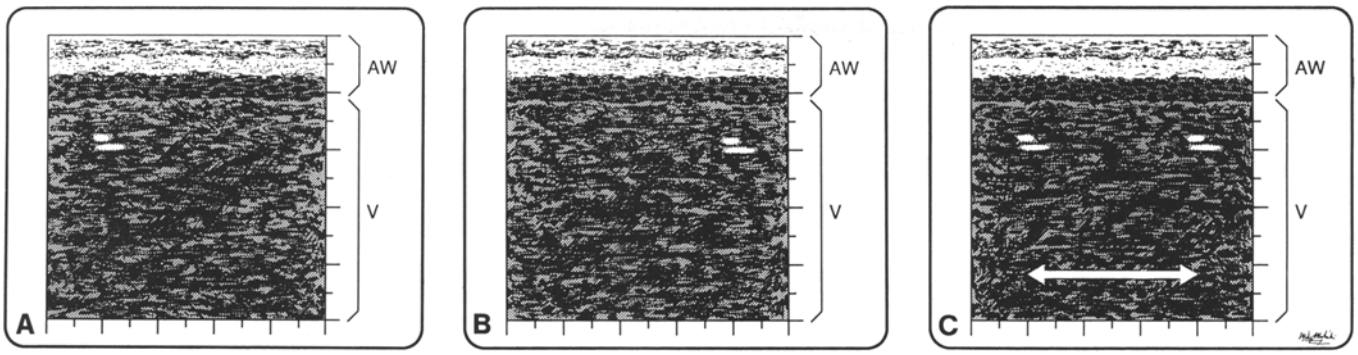

Fig. 5 A – C. Schematic representation of the ultrasound images of the abdominal wall (*AW*) and viscera (*V*) in the examination of viscera slide. A distinctive persistent cluster of echoes is identified as a focal area. In this illustration, the focal area consists of two small, white structures within a darker image background. The focal area **A** lies at the *left-hand aspect* of the monitor screen during one phase of respiration and **B** moves to the *right-hand aspect* of the monitor screen during another phase of respiration. **C** Simultaneous positions of the focal areas shown separately in **A** and **B**. The excursion distance of the focal area is depicted by the *arrow*. An electronic scale indicating 1-cm and 0.5-cm marks reveals that the excursion distance is 3 cm

sequently, by all means of observation conducted with the patient in the supine position, we have defined restricted viscera slide as representing <1 cm of horizontal motion at a given point on the abdominal wall during longitudinal scanning of spontaneous viscera slide produced by regular and deep respirations and during longitudinal and transverse scanning of induced viscera slide produced by manual compression (equivalent to that used during a normal physical examination; Fig. 6C, D).

For the most complete evaluation of restricted viscera slide, longitudinal spontaneous as well as longitudinal and transverse induced viscera slide should be observed. If spontaneous viscera slide appears restricted, the patient should be asked to take deep breaths and the extent of longitudinal slide should be noted. The observation of induced viscera slide is particularly helpful in patients who are unresponsive or otherwise unable to produce normal or exaggerated respiratory movements.

The search for restricted viscera slide should begin at points of special interest for the surgeon, including examination beneath visible scars of previous abdominal operations and sites of proposed entry for laparoscopic (or other) surgery. If normal viscera slide is demonstrated at

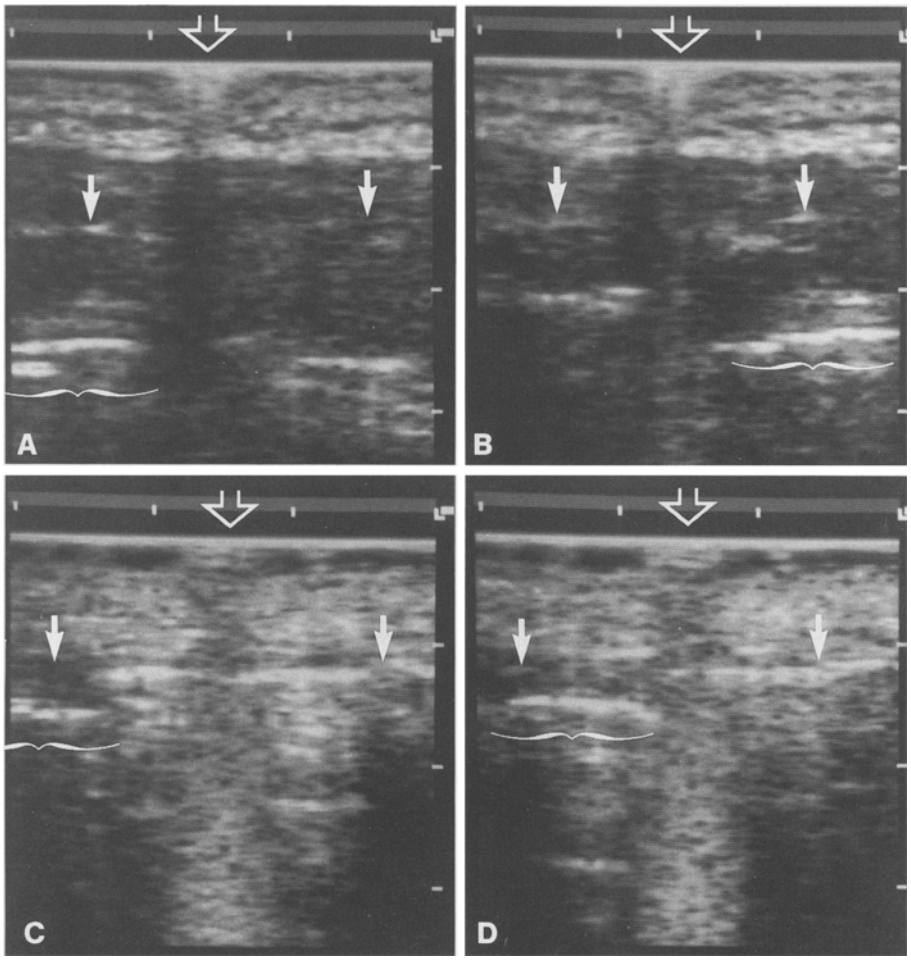

Fig. 6 A, B. Sonogram of normal viscera slide. **A** and **B** represent phases of respiration during which the focal area (*brackets*) shows the greatest excursion distance. An acoustic shadow from a stationary metal marker (*open arrow*) has been inserted for a better demonstration of the extent of displacement of the focal area. *Closed arrows* indicate the junction between the abdominal wall and the viscera. As determined by the electronic scale at the top of each sonogram, the excursion distance is 2 cm. **C, D.** Sonogram of restricted viscera slide. **C** and **D** represent the excursion distance of the focal area (*brackets*), which has moved <1 cm in reference to the acoustic shadow produced by the metal marker (*open arrow*). *Closed arrows* indicate the junction between the abdominal wall and the viscera

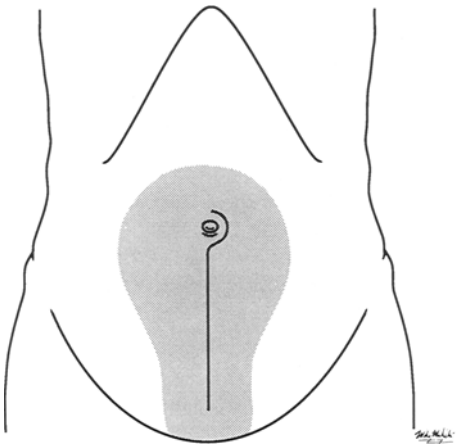

Fig. 7. Mapping of an area of restricted slide is shown as a *shaded area* in the lower abdomen in relation to the vertical midline abdominal incision

these points of interest, the ultrasound examination can usually be concluded. On the other hand, if restricted slide is observed during the detection phase of the ultrasound examination, mapping of the areas of restricted viscera slide should be performed as a guide to the location of adhesions between the proposed site of entry and the probable region of operative interest.

Mapping of restricted viscera slide is intended to document the spatial distribution of areas in which abdominal wall adhesions are likely to be present. Ultrasonic mapping of restricted viscera slide is carried out by systematically scanning contiguous areas of the anterior abdominal wall and noting the topographic extent of the abnormal viscera slide. Such mapping is most easily achieved by observing longitudinal scans of spontaneous viscera slide. If restricted viscera slide can be reliably demonstrated by spontaneous viscera slide, induced viscera slide is usually not needed for mapping (Fig. 7).

Results

Our preliminary results have been elsewhere [1]. A total of 42 subjects underwent ultrasound examination for the detection of viscera slide. The subjects were regarded as being either "normal" or at "risk" for adhesions on the basis of previous abdominal surgery or a history suggestive of peritonitis. There were 18 individuals in the normal group and 24 in the risk group. All but one of the risk-group subjects had previously undergone abdominal surgery and demonstrated healed surgical scars. One risk-group subject who had not undergone an abdominal operation exhibited a history of pelvic inflammatory disease. The presence or absence of adhesions was confirmed in 18 subjects who underwent laparoscopy or laparotomy within 1 week of the ultrasound examination.

Using our definition of restricted viscera slide as an excursion distance of <1 cm for both spontaneous and induced viscera slide, we made the following observations. All normal subjects were found to display excursion distances of >1 cm for both spontaneous and induced viscera slide. The excursion distances for spontaneous viscera slide were >2 cm in these individuals. Risk-group subjects demonstrated both normal and restricted viscera slide. In all, 10 risk-group subjects demonstrated no abnormal viscera slide, whereas 14 patients in this group exhibited restricted viscera slide. Thus, 58.3% of the subjects who had previously undergone abdominal operations or exhibited a history of peritonitis showed restricted viscera slide.

Operative confirmation of adhesions was achieved in 18 subjects who underwent laparoscopy or laparotomy within 1 week of the ultrasound examination. Five normal and six risk-group subjects exhibiting normal viscera slide demonstrated no abdominal wall adhesions at operations. Four subjects who exhibited both restricted spontaneous and induced viscera slide displayed adhesions at the sites that corresponded to the locations of the abnormal ultrasound findings. In three subjects, spontaneous viscera slide was restricted, whereas induced viscera slide was normal. At operation, filmy adhesive bands were found attached to the abdominal wall at the site of the restricted viscera slide in two of these subjects.

Discussion

The problem of visceral puncture during the blind insertion of the first trocar during laparoscopy in patients who have previously undergone surgery has prompted some surgeons to employ open laparoscopic access in patients who are at risk [3]. Our preliminary experience indicates that ultrasound examination of the abdomen for viscera slide is a promising, simple diagnostic technique that may be useful in identifying and mapping abdominal wall adhesions prior to laparoscopy. Such an ultrasonic study could obviate the need for more extensive laparoscopic access procedures at sites at which adhesions are shown to be absent and could help to select alternative sites for initial access if adhesions are found at the usual entry sites. Thus, preoperative ultrasound examination could enhance the safety of peritoneal cavity access in patients exhibiting abdominal wall adhesions.

The premise that restricted viscera slide indicates the presence of adhesions between the intraperitoneal structures and the abdominal wall is supported by two observations. First, restricted viscera according to our definition was found in 58.3% of subjects displaying healed abdominal scars from previous operations or peritonitis and was not detected at all in those who exhibited no history of previous surgery or peritonitis. Second, viscera slide findings corresponded in all instances to operative findings in subjects who underwent post-ultrasound abdominal operations. In two of three subjects in whom spontaneous viscera slide was restricted but induced viscera slide was not, filmy adhesions were detected at the site of restricted spontaneous viscera slide. These findings suggest that spontaneous viscera slide restriction may be a more sensitive indicator of adhesions than induced viscera slide. These observations also suggest that the association of restricted spontaneous with normal induced viscera slide may indicate less dense or less extensive adhesions.

Assessment of spontaneous viscera slide should be the primary ultrasound examination for the detection and mapping of abdominal wall adhesions. The reliability of spontaneous viscera slide as an indicator of adhesions is established if restricted viscera slide is observed only locally. In

other words, if spontaneous viscera slide is normal in one part of the abdomen but restricted in another part, adhesions are very likely to be present in areas exhibiting restricted slide. If spontaneous viscera slide is restricted throughout the abdomen, the possibility of inadequate respiratory movement (for example, pulmonary disease or an uncooperative patient) must be considered before the diagnosis of extensive abdominal wall adhesions is made.

Induced viscera slide examination should be performed in areas that exhibit restricted spontaneous viscera slide. Such an examination either confirms spontaneous viscera slide abnormalities or provides a better insight into the significance of abnormal spontaneous viscera slide. Thus, normal induced viscera slide in the presence of restricted spontaneous viscera slide in all abdominal areas strongly suggests inadequate respiratory movement, and normal induced viscera slide in an isolated area of restricted spontaneous viscera slide suggests that less extensive local adhesions may be present.

In summary, we propose the following uses of spontaneous and induced viscera slide. For detection of adhesions, we recommend that induced viscera slide be carried out in instances in which spontaneous slide is abnormal. For mapping of the extent of adhesions, we recommend that only spontaneous viscera slide examination be performed if it is reliable (that is, in subjects exhibiting adequate respiratory movement). Detailed mapping may be time-consuming and spontaneous viscera slide examination can be performed rapidly, particularly if a linear-array transducer capable of providing a long footprint is used.

Ultrasound has previously been proposed for the detection of abdominal wall adhesions based on the comparison of ultrasound scans before and after the induction of pneumoperitoneum [2]. The technique described in the present report has the advantage of being totally noninvasive. The ultrasound examination that we perform may be done at any time before the operation. Thus, ultrasonic detection and mapping of adhesions can be incorporated with other ultrasound examination that may precede laparoscopic surgery. For example, ultrasonic detection and mapping of adhesions could be added to the ultrasound examination of biliary calculi in patients exhibiting biliary stones who have undergone and may be candidates for laparoscopic cholecystectomy.

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