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Evaluation of a protocol for fast localised abdominal sonography of horses (FLASH) admitted for colic

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ABSTRACT

The aim of this prospective study was to establish a protocol for fast localised abdominal sonography of horses (FLASH) admitted for colic. The FLASH protocol was then presented to clinicians without extensive ultrasound (US) experience to determine whether they could learn to use it in less than 15 min. The clinical subjects comprised 36 horses that had been referred for colic over a 2 month period. Each horse was examined at admission and FLASH findings at seven topographical locations were compared to serial clinical examinations, surgical and non-surgical outcomes, or with post-mortem reports.

FLASH was able to show free abdominal fluid and abnormal intestinal loops, with a mean time of 10.7 min required to complete the protocol. The positive and negative predictive values of requirement for surgery of dilated turgid small intestinal loops using FLASH were 88.89% and 81.48%, respectively. The results suggested that FLASH is a technique that can be used in an emergency setting by veterinarians without extensive US experience to detect major intra-abdominal abnormalities in horses with colic.

Introduction

Colic is a frequent cause of emergency calls for equine veterinarians, ranked first in importance among medical problems (Traub-Dargatz et al., 1991, 2001; Tinker et al., 1997). There are many causes for colic, ranging from mild to life-threatening or fatal diseases (Abutarbush et al., 2005). One of the main challenges for the equine clinician is early recognition of potentially fatal causes and identification of the need for abdominal surgery (Fischer, 1997).

Abdominal ultrasound (US) has been demonstrated to be accurate for detecting small intestine outflow obstructions (Klohnen et al., 1996; Freeman, 2002a) and has become a part of the acute abdomen diagnostic work-up in many equine clinics. Although hand-held US equipment may increase the speed of US in equine patients, US evaluation of the entire equine abdomen is time consuming and difficult to carry out at admission or under field conditions. Focused abdominal US is used in humans and small animals to detect free fluid in emergency patients with blunt abdominal trauma (Boysen et al., 2004; Soudack et al., 2004; Kirkpatrick et al., 2005; Soundappan et al., 2005). The advantage is a rapid non-invasive technique that can be used for early evaluation and for triage following arrival at the emergency clinic (Blaivas, 2001; Walcher et al., 2006; Helling et al., 2007; Lee et al., 2007).

A focused abdominal US procedure to be used in horses during admission at the emergency clinic has not been previously described. The aims of this study were: (1) to establish a protocol for fast localised abdominal sonography of horses (FLASH) admitted for colic; (2) to assess the usefulness of a fast US examination limited to specific abdominal regions; and (3) to determine whether FLASH can be performed by clinicians without extensive experience in equine abdominal US in less than 15 min.

Materials and methods

A prospective trial was undertaken on client-owned horses referred for colic at the University of Liège over a 2 month period. Horses were examined within 2 h of admission. Prior to perform FLASH on client-owned horses, five veterinary clinicians without extensive experience of equine abdominal US were trained for 1 h by an experienced radiologist. Horses were included in the study if one of the previously trained clinicians was available at the time of admittance. A table summarising the topographical locations examined with FLASH, normal reference values and examples of normal and abnormal images was given to the trainees.

A hand-held (SonoSite 180PLUS, Bothell) or a portable (Aloka SSD 900, Aloka Holding Europe) US machine, equipped with a 3–3.5 MHz transducer (microconvex and curvilinear, respectively), was used.

Seven topographical locations were assessed using alcohol and without clipping: (1) ventral abdomen; (2) gastric window; (3) spleno-renal window; (4) left middle third of the abdomen; (5) duodenal window; (6) right middle third of the abdomen; and (7) thoracic window. The operators were requested to assess the seven sites starting from the ventral abdomen. Table 1 describes topography and procedure to scan each site.

At each location at least one image was recorded. All recorded images were reviewed for presence or absence of free fluid and dilated turgid small intestinal loops by a board certified radiologist (VB). Because only static images were recorded, intes-

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Table 1
Topographical locations of the abdomen assessed transcutaneously during fast localised abdominal sonography of horses (FLASH) with colic symptoms and procedure to scan each location.

Side	Site	Scanning procedure
Left	1. Ventral abdomen	Place the probe just caudal to the sternum and move caudally to assess the most gravity dependent area of the abdomen
	2. Gastric window	Visualise the stomach at the level of the 10th left ICS in the middle third (dorso-ventrally) of the abdomen and then move the probe in the 2–3 ICSs cranial and caudal to the 10th
	3. Spleno-renal window	Place the probe between dorsal and middle third of the abdomen at the level of the 17th ICS
	4. Left middle third of the abdomen	Freely move the probe around in the middle third of the abdomen
Right	5. Duodenal window	Place the probe in the 14–15th right ICS in the dorsal part of the middle third (dorso-ventrally) of the abdomen
	6. Right middle third of the abdomen	Freely move the probe around in the middle third of the abdomen
	7. Cranial ventral thorax	Place the probe on the cranial ventral thorax just caudal to the triceps muscle

ICS – intercostal space.

tinal motility was not evaluated retrospectively. The time used to undertake FLASH was measured from when the probe was first placed on site 1 to completion of assessment of site 7. Preparation time for the horse or the US machine was not included.

The results of each FLASH examination were collected using a standardised form (Fig. 1). The ability of FLASH to detect free fluid, to see the left kidney, to evaluate small bowel filling, turgidity and motility and large intestinal content was assessed.

FLASH results were compared retrospectively with the findings from serial clinical examinations, surgical and non-surgical outcomes, or with post-mortem reports. Data collected about presence of free abdominal fluid and dilated turgid small intestinal loops were compared to the radiologist's retrospective reading. Sensitivity, specificity, positive and negative predictive values of the presence of dilated turgid small intestinal loops for small intestinal obstruction and for requirement for surgery were calculated.

Results

Thirty-six horses were included prospectively (20 mares, 12 geldings, 4 stallions). The age of the horses (rounded to the nearest year) ranged from 2 to 28 years (mean 14 years). Warmbloods were the most represented (27 horses) and this reflected the hospital population.

The five clinicians trained for FLASH comprised three equine interns, one equine surgery resident and one radiology resident. The number of examinations undertaken by each operator varied considerably. The radiology resident performed most of FLASH examinations (20), one was done by the surgery resident and the remaining 15 were equally distributed among the interns. The time used for FLASH ranged between 7 and 17 min, with only three studies lasting more than 15 min and a mean time used of 10.7 min. FLASH duration was $\leqslant$10 min in 21/36 patients. The three examinations lasting more than 15 min had been performed by two interns (16 and 17 min) and by the radiology resident (16 min).

All the operators were able to obtain US images without clipping. In two instances, there was a disagreement between the retrospective readings and the data collected. The disparity concerned the aspect of small intestinal loops that had been defined as dilated non-turgid by the examiners, and as turgid by the radiologist. There was no disagreement concerning detection of an abnormal amount of abdominal fluid.

Of the 36 horses, 23 had a medical colic (17 had a positive outcome, six were euthanased). Thirteen horses had a surgical colic (10 small intestinal obstructions, one colon displacement, two nephrosplenic entrapments). A definitive diagnosis was available for 10/23 medical cases. FLASH was able to show free abdominal fluid, abnormal small intestinal loops and abnormal colon content (Figs. 2–5). Free fluid was mainly detected ventrally. Sites where abnormal small intestinal loops were seen were not recorded. Abnormal large intestine content was mainly observed in site 1 or in sites 5–6 when the dorsal right colon or caecum were involved, respectively.

An increased amount of free fluid was seen in 10 horses (four with strangulated small intestinal obstruction, six with medical colic). In one horse with medical colic, free pleural fluid was also detected. The left kidney was seen in 29/36 horses, while 2/7 horses in which the left kidney was not seen had a nephrosplenic entrapment. In these horses, images obtained at the spleno-renal window demonstrated US features typical of nephrosplenic entrapment (gas-filled colon between spleen and left kidney obscuring the kidney, ventral spleen displacement; Fig. 6).

The duodenum was observed in all 36 cases and appeared normal in 31 horses. In five horses, the duodenum was fluid-filled, dilated, but non-turgid. Duodenal motility was considered absent in two horses with proximal enteritis.

The small intestine other than duodenum was seen in 27/36 horses (75%). In five horses it had a normal appearance, while 7/9 horses without visible small intestine had a medical colic with positive outcome. The remaining two horses had a small intestinal obstruction and a nephrosplenic entrapment, respectively. Four of the five horses with normal small intestine visible had a pelvic flexure impaction, while the fifth had a small intestinal obstruction.

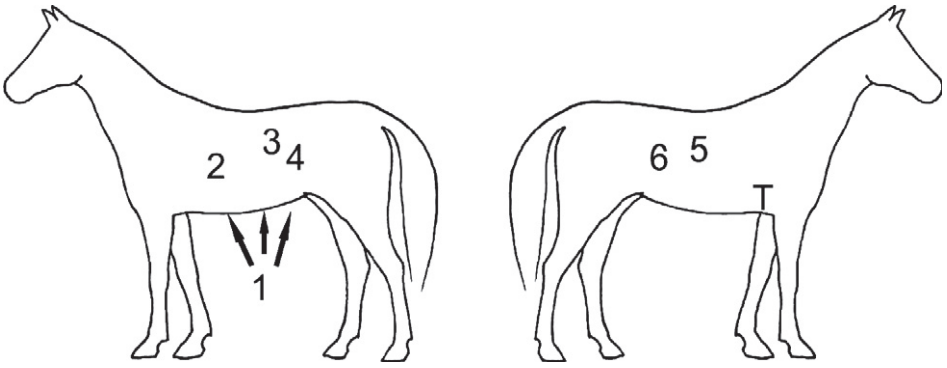
Evidence of dilated turgid small intestinal loops on US images was associated with surgical colic due to small intestinal obstruction in eight horses and with proximal enteritis in one. Only in 2/10 horses with small intestinal obstruction the small intestine was not seen (one horse) or seemed normal (one horse). Non-turgid fluid-filled small intestinal loops were seen in two horses with simple large bowel displacement (one with nephrosplenic entrapment) and in 11 horses with medical colic. Total absence of small intestinal motility was reported in six horses (three small intestinal obstructions, three medical colics with negative outcomes). In all horses with small intestinal strangulated obstruction motility was reported as absent or reduced. Horses with large intestinal disease had small intestinal motility reported as normal. Thickening of the small bowel wall was reported in two cases with non-turgid and turgid small intestinal loops with respectively infiltrative bowel disease and strangulated small intestinal obstruction.

The colon was defined as normal in 31/36 horses. The only abnormality recorded for the colon was abnormal liquid content (five horses). Fluid content in a large intestine segment, while other portions had a normal appearance, was seen in four horses with colon impaction. No increased colon wall thickness was reported.

The presence of dilated turgid small intestinal loops was 80% sensitive and 96.15% specific for small intestinal obstruction. Positive and negative predictive value of this US sign for small intestinal obstruction were 88.89% and 92.59%, respectively. Sensitivity, specificity, positive and negative predictive values of dilated turgid small intestinal loops for surgical need were 61.54%, 95.65%, 88.89% and 81.48%, respectively, with 2/5 false negative having a nephrosplenic entrapment.

Id (Horse — Owner) .....
Examiner .....
Date ..... **Time** .....

Nasogastric tube in place YES NO



Abnormal amount of *free fluid* YES NO

Dilation of the *stomach* YES NO

Duodenum

normal ☐
liquid content, non turgid ☐
dilated and turgid ☐

Motility YES norm or > ☐
YES reduced ☐
NO absent ☐

Other loops of *small intestine* visible YES NO

normal ☐
liquid content, non turgid ☐
dilated and turgid ☐

Motility YES norm or > ☐
YES reduced ☐
NO absent ☐

presence of thickened wall loops YES NO

Colon

normal ☐
ventral liquid content (1) ☐
lateral liquid content (4, 5 ou 6) ☐

Motility YES norm or > ☐
YES reduced ☐
NO absent ☐

presence of a thickened wall portion YES NO

L kidney visualized YES NO

Thorax : free fluid YES NO

Length of the US exam (min) .....

Fig. 1. Standardised form used to collect data by each examiner.

Discussion

Focused assessment with sonography in trauma (FAST) was first described in human patients admitted at an emergency clinic for blunt abdominal trauma (Rozycki et al., 1993, 1995; McGahan et al., 1997). The aim of FAST is to detect free abdominal fluid (Kimura and Otsuka, 1991; Pearl and Todd, 1996; Soundappan et al., 2005) and, in humans, has a reported good sensitivity and specific-

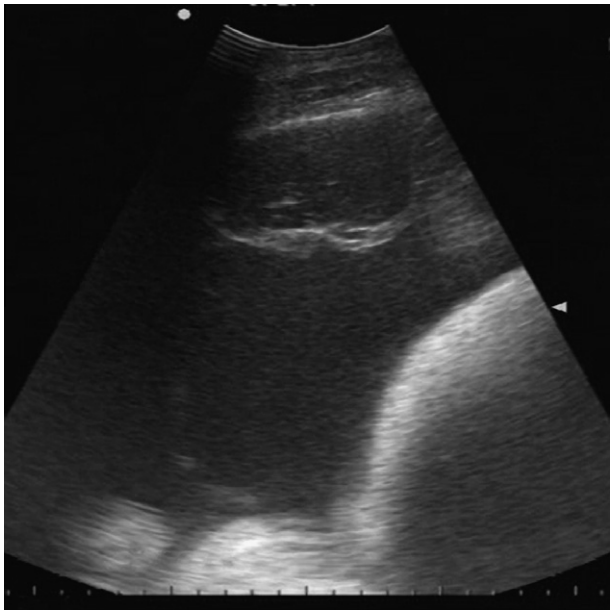


Fig. 2. Ultrasonographic image obtained at site 1: an abnormal amount of anechoic free fluid is visible.

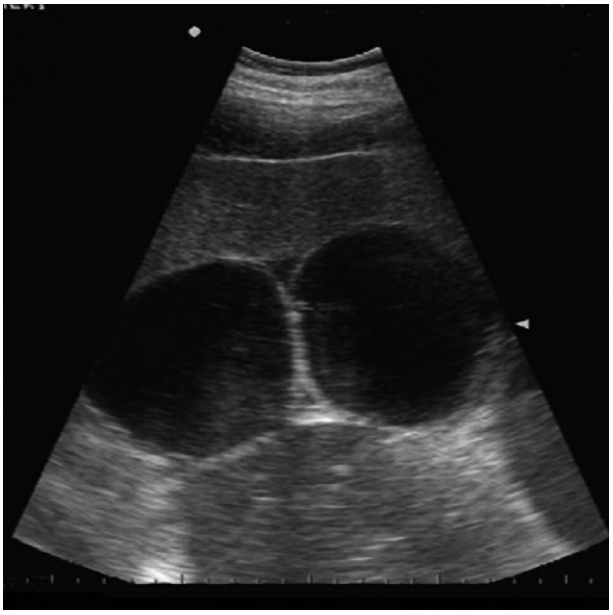


Fig. 4. Ultrasonographic image showing turgid small intestinal loops without wall thickening in a horse with small intestinal obstruction.

Fig. 3. Ultrasonographic image showing non-turgid fluid-filled small intestinal loops.

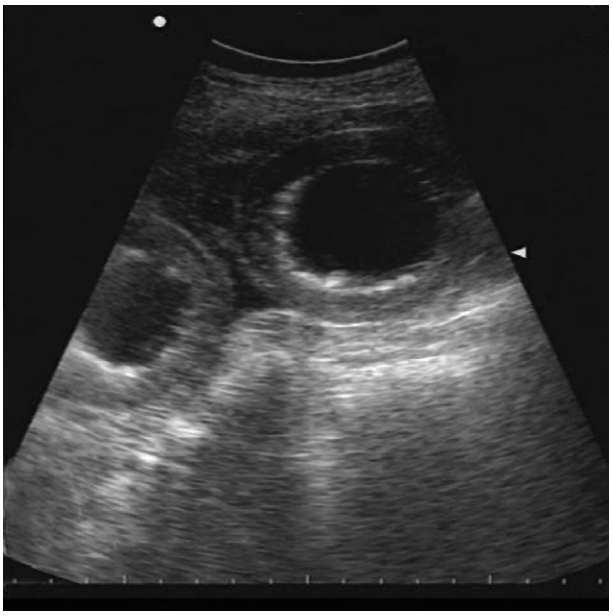


Fig. 5. Ultrasonographic image showing turgid small intestinal loops with marked wall thickening in a horse with strangulated small intestinal obstruction.

ity ⩾90% (Gruessner et al., 1989; Liu et al., 1993; Rozycki et al., 1993, 1995; McKenney et al., 1996; McGahan et al., 1997).

In FLASH, detection of an increased volume of abdominal fluid was only one of the aims of the focused abdominal US. A small amount of free anechoic abdominal fluid can normally be observed in the horse (Freeman, 2002b) and is routinely collected by non-US-guided abdominocentesis in patients admitted for colic. FLASH forms recorded only cases in which the amount of fluid was subjectively considered increased. No sensitivity or specificity of FLASH for fluid detection in comparison with abdominocentesis or other procedures was calculated, although this has been done for FAST in dogs (Soundappan et al., 2005) and humans (Gruessner et al., 1989; Liu et al., 1993; McKenney et al., 1996). Although some information about quantity and character of peritoneal fluid can be obtained by US (Reef et al., 2004), the type of fluid cannot accurately be determined and FLASH results should be interpreted in conjunction with peritoneal fluid analysis.

FAST in humans and dogs is routinely performed in less than 10 min (Kimura and Otsuka, 1991; Pearl and Todd, 1996; Blaivas, 2001; Soundappan et al., 2005; Helling et al., 2007; Lee et al., 2007). In the present study, the mean elapsed time was 10.7 min, with only three studies lasting more than 15 min. A time of 15 min was considered adequate for an examination to be performed at admission of an emergency patient while other procedures are undertaken on the horse, such as placement of an intravenous catheter or nasogastric tube, or rectal palpation in a stock.

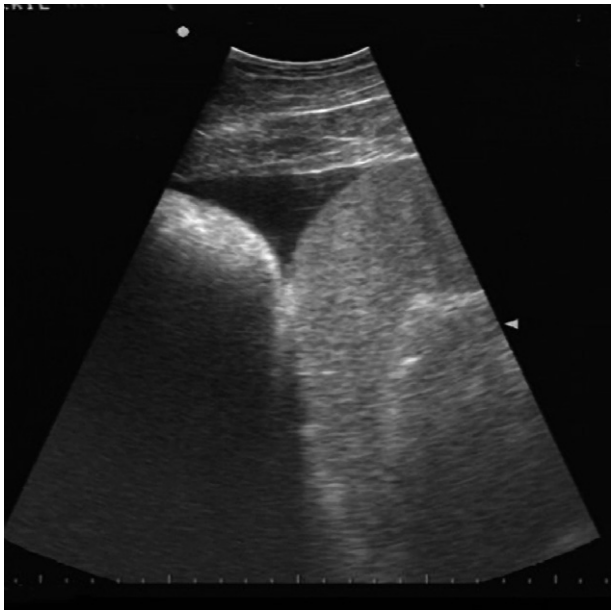


Fig. 6. Ultrasonographic image obtained at site 3 (spleno-renal window) in a horse with nephrosplenic entrapment. Dorsal is to the left, ventral to the right. The dorsal portion of the spleen is displaced axially and partially obscured by the gas-filled colon.

The protocol and the US windows chosen for FLASH were established on the basis of available literature in order to explore topographical locations where abdominal US abnormalities are most commonly seen (Reef, 1998; Freeman, 2002b; Scharner et al., 2002). Because the duodenum, stomach and left kidney were seen either in all or on the majority of horses by all the operators, the simple landmarks used for FLASH can be considered routinely applicable in clinical conditions. The ventral thoracic window was chosen based on clinical experience. Because the aim was to detect pleural effusion, only the ventral aspect of the thorax was assessed (Busoni, 2009).

A low frequency transducer was used to evaluate transcutaneously the abdominal content, including the left kidney (Reef, 1998; Reef et al., 2004). Practitioners having only high frequency probes (>7.5 MHz) will not be able to apply the complete FLASH procedure because of lack of penetration. However, using high frequency transducers and partially applying the FLASH protocol, they will be able to assess with optimal resolution, structures close to the abdominal wall and presence of peritoneal/pleural fluid in non-obese patients (Freeman, 2002b; Reef et al., 2004).

Our study focused on the detection of common abnormal findings previously reported in horses with colic (Freeman, 2002a; Scharner et al., 2002; Reef et al., 2004). The results and the few cases of disagreement between recorded data and retrospective reading suggest that major intra-abdominal abnormalities explored could be correctly imaged and interpreted by examiners with minimal training. However, most of the FLASH examinations were interpreted by the radiology resident who, although she did not have extensive experience in equine abdominal US at the time, had more experience in reading US images. This may have created a bias in the results, even though only two cases of disagreement were recorded for the other four examiners performing the remaining 16 examinations. In fact, although it has been demonstrated that simple image recognition can be taught by using relatively basic and short teaching modules (Noble et al., 2009), the effectiveness of FLASH (as with any US examination) is higher with increasing operator experience.

The small intestine was visible in most horses (duodenum in 100%, small intestine other than duodenum in 75% of the horses). These high percentages suggest that the windows chosen mostly covered the areas where small intestine might be observed in colic patients. However, because of the focused nature of FLASH and because horses did not undergo a complete abdominal US after FLASH, it cannot be excluded that dilated loops would have been seen in other locations in false negative cases.

In agreement with previous studies (Klohnen et al., 1996; Scharner et al., 2002), the presence of dilated turgid small intestinal loops was highly sensitive and specific (80% and 96.15%) for small intestinal obstruction and had high positive and negative predictive values (88.89% and 92.59%). Lower sensitivity and lower predictive values for surgical need are due to a relative high number of false negative results. Although the number of horses requiring surgery for large intestinal disease was very low, the inclusion of large intestine surgical disorders in the calculation of the diagnostic values for surgical need necessarily influenced the results.

Since a definitive diagnosis was not possible for a relatively high number of cases, it was difficult to evaluate the ability of FLASH to discriminate ileal impaction and proximal enteritis (that may show dilated turgid small intestinal loops at US) from surgical cases. Although certain tests, including degree of pain, response to analgesia, abdominal US, abdominal fluid colour and protein content, have been reported to be strongly predictive of the need for surgery, no single diagnostic test is 100% accurate (Nolen-Walston et al., 2007). It is therefore evident that additional diagnostic procedures, such as peritoneal fluid analysis, should always be included in assessing a colic patient, particularly in areas with higher incidence of ileal impactions (e.g. South-eastern United States) where it is important to differentiate these from strangulated small intestinal lesions (Plummer, 2009).

Images were reviewed by a Board certified radiologist to estimate the amount of free fluid and to interpret any changes in the small intestinal. In two cases, there was a disagreement between recorded data and retrospective interpretation concerning loop turgidity. Based on static images, it may not be easy to define if small intestinal dilated loops are turgid or not and lack of motility should therefore be used to discriminate between surgical versus non-surgical cases in horses with small intestinal disease (Klohnen et al., 1996; Freeman, 2002a).

We did not verify recorded results of large intestine wall thickness, despite this being a useful parameter to predict torsion in the large colon (Pease et al., 2004). We also did not observe a case of large colon volvulus, so it was impossible to evaluate the usefulness of FLASH to diagnose this condition.

Nephrosplenic entrapment was seen at the nephrosplenic window with the typical US appearance (Santschi et al., 1992; Reef et al., 2004). Inability to see the left kidney is not entirely reliable for a diagnosis of nephrosplenic entrapment (Scharner et al., 2002), although the additional use of rectal palpation can be used to exclude nephrosplenic entrapment.

Several studies about FAST in humans have highlighted its limitations and occasionally inability to detect serious injuries requiring surgery (McGahan et al., 1997; Shanmuganathan et al., 1999; Brown et al., 2001; Nunes et al., 2001). Although operators with little experience can perform FLASH, better results are generally obtained with experience. Furthermore, FLASH will primarily be used in emergencies in well lit rooms, alongside other simultaneous procedures, on horses experiencing pain, with portable equipment and limited time, all of which will reduce the diagnostic accuracy of FLASH. In the current study, there were relatively few cases, some without a definitive diagnosis, which made conclusions about the utility of FLASH in specific diseases difficult and for this reason diagnostic values were only calculated for the most prevalent condition, namely, small intestinal obstruction.

Conclusions

This study suggests that FLASH is a technique that can be used in an emergency setting by veterinarians without extensive US experience to detect major intra-abdominal abnormalities in horses with colic. However, horses with persistent symptoms and negative FLASH should still undergo a comprehensive abdominal US examination (or serial exams) as a part of follow-up during clinical observation.

Conflict of interest statement

None of the authors of this paper has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

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