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Ultrasound assessment of gastric emptying and the risk of aspiration of gastric contents in the perioperative period

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Abstract

The risk of aspiration of gastric contents in the perioperative period constitutes a serious clinical problem and it is connected with increased mortality. At present, the risk of aspiration is assessed only on the basis of an interview and information obtained from the patient. Such an assessment is not always reliable while the concomitance of some additional factors influencing the delay of gastric emptying significantly decreases its sensitivity. Using bedside ultrasound imaging in an assessment of gastric contents is a method which supports an objective, simple and quick assessment of the risk of aspiration, helps one to optimise perioperative anaesthetic management, and should constitute a routine element of the perioperative patient assessment.

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Key words: aspiration of gastric contents, ultrasonography, gastric emptying

The risk of aspiration of gastric contents is a serious clinical problem that is directly associated with increased perioperative morbidity and mortality [1–4]. The key preventive measures to avoid gastric content aspiration and respiratory complications include adequately long preoperative food and fluid fasting in individuals scheduled for elective surgical procedures, as well as proper selection of the induction method and type of anaesthesia [5]. The risk assessment based exclusively on patient-provided information regarding the most recent meal is not infallible. Many conditions and clinical situations are associated with an increased risk of aspiration or are likely to hinder its proper assessment [1]. The situations in which no suitable food and fluid fasting periods are observed include emergency or urgent procedures, communication problems and incomprehension of instructions, impaired cognitive functions, paediatric patients or language barriers. Moreover, the conditions hindering (delaying) gastric emptying, such as pregnancy, past trauma or surgery, diabetes mellitus, obesity, impaired kidney and liver functions, Parkinson`s disease, and neuromuscular diseases, significantly increase the risk of aspiration [6, 7]. The gold standard for assessing gastric emptying is scintigraphy with a standardised radiopharmaceutical-labelled test meal [8]. Although very accurate, the method is virtually useless for routine preoperative assessment. An equally objective, as well as widely available, quick, easy and repeatable bedside method for assessing the risk of aspiration is ultrasound imaging of the stomach and evaluation of its liquid and solid contents [9–13]. Whenever there are doubts concerning a risk assessment, ultrasound imaging of gastric emptying should be performed prior to taking any decisions about the procedure, the method of anaesthesia or Induction of anaesthesia. This kind of assessment has its limitations, which include post-gastric resection conditions, gastric banding procedures, fundoplications and large hiatus hernias. In the above cases, ultrasound assessment of gastric emptying is disturbed by the changes in the gastric antrum anatomy, which can reduce the reliability of the method.

SCANNING TECHNIQUE

In the vast majority of patients, a low-frequency "convex" transducer (2–5 MHz) is used which ensures the optimal depth of ultrasound beam penetration. A high-frequency linear transducer with a lower ultrasound beam penetration can be used in extremely lean, cachetic or debilitated patients and in children. The examination is performed in two positions namely: supine and right lateral decubitus (Figs 1 and 2). The lack of gastric contents detected in the supine

Figure 1. The ultrasound technique; placement of a transducer in the supine position

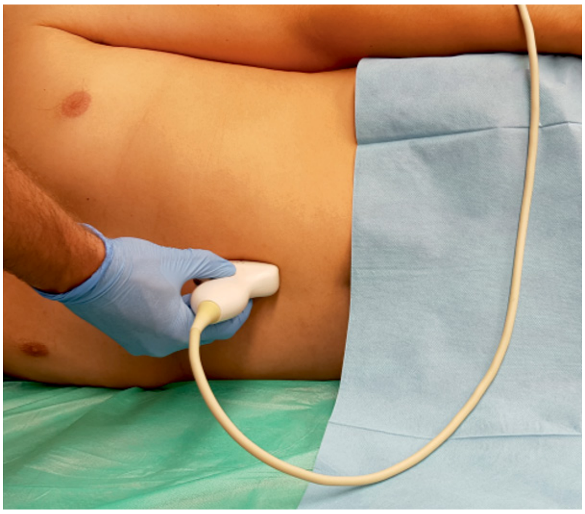

Figure 2. The ultrasound technique; placement of a transducer in the right lateral decubitus position

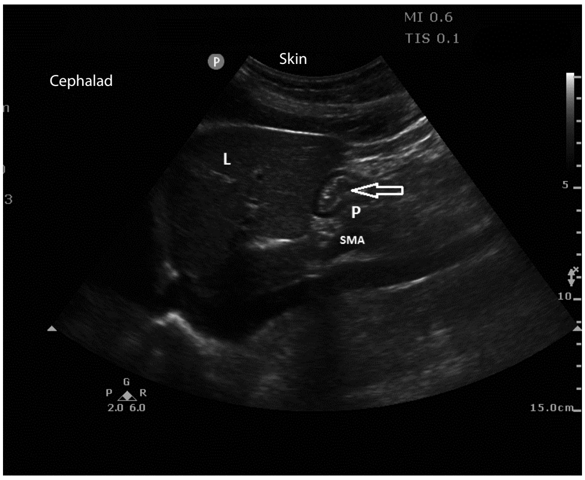

Figure 3. Sonoanatomy of the stomach; L: liver; P: pancreas, SMA: superior mesenteric artery; an arrow shows the shrunk empty stomach

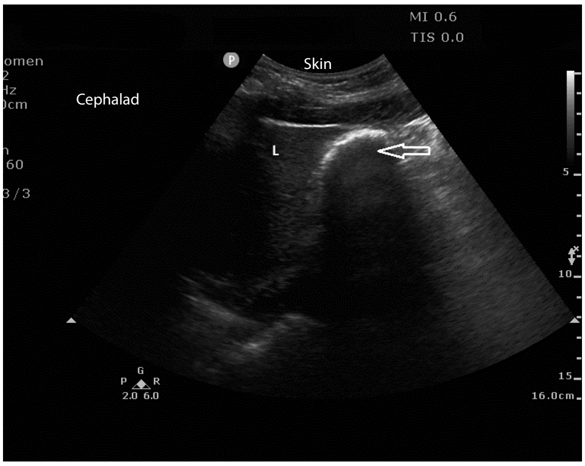

Figure 4. The sonoanatomic image of the stomach filled with solid contents (early stage of digestion); L: liver; an arrow shows ultrasound artefacts caused by the presence of air along the anterior surface of the stomach (a "frosted glass" pattern)

position does not exclude their presence in the right lateral decubitus position; therefore, in all cases the lack of gastric contents has to be confirmed in both positions [9, 14]. While choosing the optimal settings, a preset "abdominal" or "FAST" transducer with the marker directed cephalad is placed in the sagittal plane, in the medial line within the epigastrium directly under the xiphoid process (Fig. 1) and the image is optimised by slight right-left movements of the transducer.

SONOANATOMY

In the ultrasound image, the gastric antrum is most commonly located at a depth of about 3–5 cm between the left hepatic lobe and the retroperitoneal pancreas. Moreover, useful retroperitoneally placed pancreas include the abdominal aorta, inferior vena cava and superior mesentery vessels (Fig. 3).

Based on the sonoanatomic image of the gastric antrum, gastric contents can be quite accurately defined and a particular image associated with the risk of aspiration [15–17].

In the ultrasound scan, the empty stomach is thick-walled, predominantly ovoid or egg-like, less commonly flat, hollow or with some hypoechoic (dark) substance ("target pattern") (Fig. 3).

A stomach filled with solid contents in the early stage of digestion (usually up to one hour after solid food intake) has a characteristic "frosted glass" pattern, which is associated with the presence of air along the anterior stomach wall and the formation of ultrasound artefacts disturbing imaging of the deeper structures (Fig. 4). A stomach filled with solid

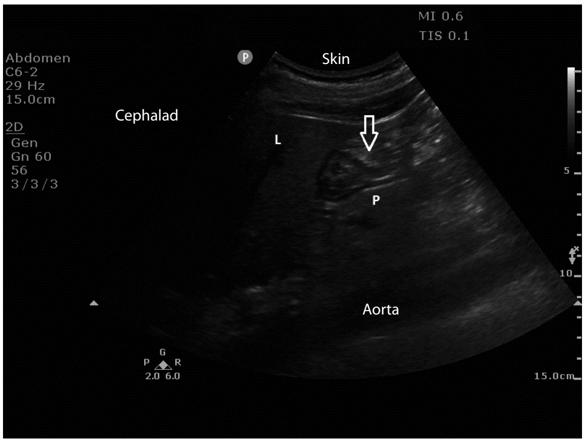

Figure 5. The sonoanatomic image of the stomach filled with solid contents (late stage of digestion); L: liver; P: pancreas; an arrow shows the stomach filled with solid heterogenous contents

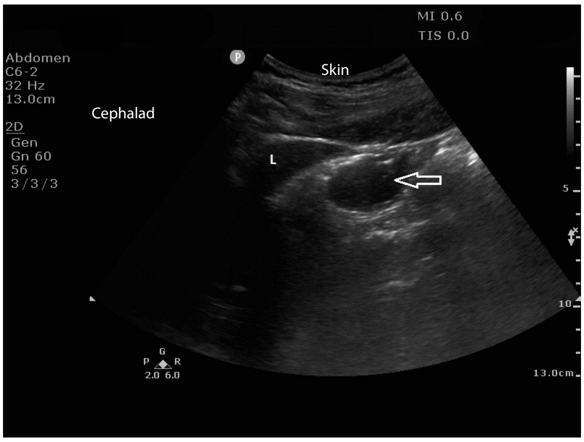

Figure 7. The sonoanatomic image of the stomach filled with clear liquids; L: liver; an arrow shows the stomach filled with clear liquids

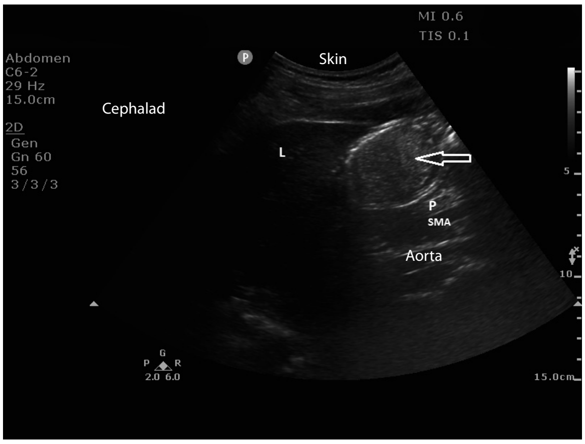

Figure 6. The sonoanatomic image of the stomach filled with milk contents; L: liver; P: pancreas, SMA: superior mesenteric artery; an arrow shows the stomach filled with solid heterogeneous contents (milk meal)

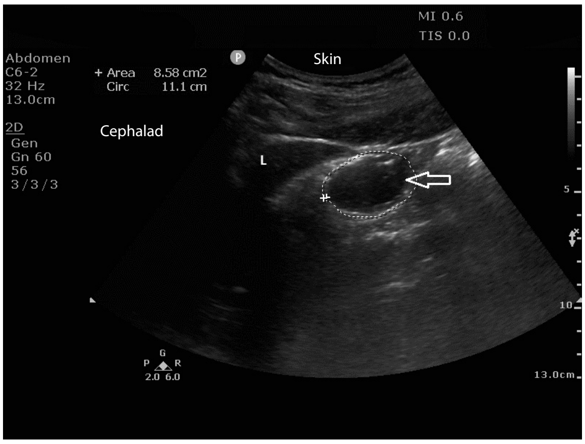

Figure 8. The sonoanatomic image of the stomach filled with clear liquids; cross-sectional area (CSA) measurement; L: liver: an arrow shows the stomach filled with clear liquids; CSA — 8.58 cm^2

contents in the later stage of digestion (usually 1–2 hours after solid food intake) is characteristically distended, thin-walled and filled with heterogeneous, fragmented contents (Fig. 5). The presence of homogeneous, highly-hyperechoic contents indicates the intake of dairy products or other liquids with an admixture of solid particles (Fig. 6).

A stomach filled with clear liquids is thin-walled, ovoid with an anechoic (dark) substance in the lumen (Fig. 7). The size (cross-sectional area) of the antrum is directly proportional to the amount of liquid. When clear liquid is detected using simple calculations and ready-to-use tables (separate tables for adults and children), it is worth estimating the volume of retained liquids, which will directly determine the risk of aspiration. To assess the volume of retained liquids, the cross-sectional area of the stomach should be calculated [8]. The measurement is made in the right decubitus position at the aorta level and the full thickness of the stomach is included (Fig. 8); the result is read from the ready-to-use tables prepared on the basis of gastroscopic evaluation of *gastric emptying* and mathematical models (Table 1) [9]. A volume of liquids equal to or lower than 1.5 mL kg^{-1} (up to 100 mL for an average adult patient) is considered normal in a fasting patient and is associated with a low risk of aspiration.

Moreover, the stomach shows a characteristic ultrasound appearance directly after the intake of carbonated drinks; the image demonstrates the presence of anechoic fluid in the lumen with numerous hyperechoic inclusion bodies, i.e., a "starry night" appearance (Fig. 9). Paediatric patients form a slightly different group. In children aged from 11 months to 17 years, separate tables are used to assess the volume of clear liquids (Table 2); based on the calculated cross-sectional area of the antrum and age, the estimated liquid volume is read [17]. In this group of patients, the cut-

Table 1. Assessment of gastric liquid volume (mL) in adults (http://www.gastricultrasound.org/Image%20Acquisition/volumeassessment.html)

CSA [cm²]	Age (years)						
	20	30	40	50	60	70	80
2	31	18	5	0	0	0	0
3	45	32	20	7	0	0	0
4	60	47	34	21	9	0	0
5	74	62	49	36	23	10	0
6	89	76	63	51	38	25	12
7	103	91	78	65	52	40	27
8	118	105	93	80	111	54	41
9	133	120	107	94	125	69	56
10	147	135	122	109	140	83	71
11	162	149	136	123	155	98	85
12	177	164	151	138	169	113	100
13	191	178	165	153	184	127	114
14	206	193	180	167	198	142	129
15	220	207	194	182	213	156	143
16	235	222	209	200	227	171	158
17	249	236	224	211	242	185	173
18	264	251	239	226	256	200	187
19	278	266	253	240	227	214	202
20	293	281	268	255	242	229	217
21	307	295	282	269	256	244	231
22	323	310	297	284	271	259	246
23	337	324	311	298	285	273	260
24	352	339	326	313	301	288	275
25	366	353	340	327	315	302	289
26	381	368	355	343	330	317	304
27	395	382	369	357	344	331	318
28	410	397	385	372	359	346	333
29	424	411	398	386	373	360	347
30	439	427	414	401	388	375	363

CSA: cross-sectional area [cm²]

off point considered safe (low risk of aspiration) is 1–1.2 mL kg^{-1} of clear liquid [19–21].

Besides the operating suite setting, the ultrasound method for assessment of gastric retention can also be used in ICU patients, in whom the nutritional intervention is planned or has already been employed through a gastric tube. Based on the ultrasound image, the presence of gastric content or gastroparesis can be evaluated (Fig. 10), which may implicate changes in clinical management in order to implement more effective nutritional interventions [22]. Additionally, during ultrasound examinations the proper positioning of the nasogastric tube can be assessed, as well as the presence or absence of peristalsis; moreover, the management in cases of elevated intra-abdominal pressure can be optimised [23].

INTERPRETATION OF FINDINGS

The detection of solid contents (both in the early and late stages of digestion) and clear liquids above 1.5 mL kg^{-1} (1–1.2 mL kg^{-1} in children) is associated with a high risk of aspiration and pulmonary complications directly increasing mortality rates. In such cases, the postponement of surgery should be considered; when not possible, the rapid sequence induction of an alternative method of anaesthesia (regional anaesthesia techniques) should be used. In pregnant women the interpretation of sonoanatomic images may be hindered due to an enlarged uterus and a substantial shifting of the anatomical structures within the epigastrium. Since there are no ready algorithms and tables for evaluation of the clear liquid volume in pregnant women, the three-degree assessment of gastric contents has been used in this group of patients until recently, i.e., empty, solid content and clear liquid with no accurate evaluation of its volume [24, 25]. At present, separate algorithms are available for patients in the third trimester of pregnancy [26, 27]. According to one study, the cut-off point of the cross-sectional area of the antrum in patients in the third trimester of pregnancy can be 9.6 cm^2 [26]. Above this value, the gastric liquid volume can exceed 1. 5 mL kg^{-1} and is associated with an increased risk of aspiration. The optimal position for evaluating gastric retention and performing measurements is considered to be the right lateral semirecumbent position [26].

In patients with pathological obesity, an increased amount of fatty tissue can hinder ultrasonograhic imaging. The selection of an appropriate depth of ultrasound penetration is essential (in the majority of obese patients, the gastric antrum can be visualised at the depth of up to 7 cm). Additionally, it should be remembered that the algorithms and tables used for evaluation of the clear liquid volume

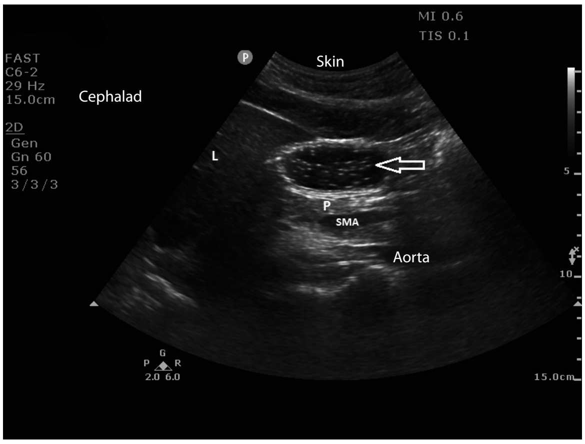

Figure 9. The sonoanatomic image of the stomach filled with clear carbonated liquids; L: liver; P: pancreas, SMA: superior mesenteric artery; an arrow shows the stomach filled with clear carbonated liquids (a "starry night" appearance)

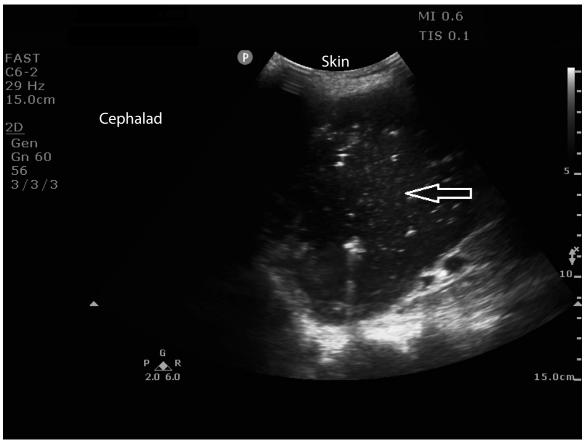

Figure 10. The sonoanatomic image of the stomach filled with high amounts of retained contents. An arrow shows the stomach filled with high amounts of retained contents (the image can correspond to gastroparesis)

Table 2. Assessment of gastric liquid volume (mL) in children (http://www.gastricultrasound.org/Special%20population/Pediatric/pediatric.html)

CSA [cm^2]	Age (in years)														
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	0	2	3	5	6	8	9	11	12	14	16	17	19	20
2	2	4	5	7	8	10	11	13	14	16	18	19	21	22	24
3	6	7	9	10	11	13	14	16	18	19	21	23	24	26	27
4	9	11	12	14	15	17	18	20	21	23	25	26	28	29	31
5	13	14	16	17	19	20	22	23	25	26	28	30	31	33	34
6	16	18	19	21	22	24	25	27	28	30	31	33	35	36	38
7	20	21	23	24	26	27	29	30	32	33	35	37	38	40	41
8	23	25	26	28	29	31	32	34	35	37	38	40	42	43	45
9	27	28	30	31	33	34	36	37	39	40	42	44	45	47	48
10	30	32	33	35	36	38	39	41	42	44	45	47	49	50	52
11	34	35	37	38	40	41	43	44	46	47	49	51	52	54	55
12	37	39	40	42	43	45	46	48	49	51	52	54	55	57	59
13	41	42	44	45	47	48	50	51	53	54	56	58	59	61	62
14	44	46	47	49	50	52	53	55	56	58	59	61	62	64	66
15	48	49	51	52	54	55	57	58	60	61	63	65	66	68	69

CSA: cross-sectional area [cm^2]

concern patients a body mass index (BMI) < 40 kg m^{-2} and should not be applied to patients with a higher BMI [28].

SUMMARY

Ultrasonograhic imaging is a useful tool not only for regional anaesthesia or in intensive care units but it also enables an objective, easy, quick and bedside assessment of gastric retention, based on which the risk of aspiration of gastric contents can be determined. The evaluation of gastric retention in patients undergoing surgical procedures facilitates therapeutic decisions, the selection of optimal types of anaesthesia or techniques of induction and should be more widely used as a routine element of preoperative evaluation of patients.

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