

Serial Ultrasonographic-measurement of Gastric Residual Volume in Critically Ill Patients for Prediction of Gastric Tube Feed Intolerance

Basavaraj Ankalagi¹, Preet Mohinder Singh², Vimi Rewari³, Rashmi Ramachandran⁴, Richa Aggarwal⁵, Kapil Dev Soni⁶, Debashish Das⁷, Kumble Seetharama Madhusudhan⁸, Deep Narayan Srivastava⁹, Manpreet Kaur¹⁰, Anjan Trikha¹¹

Received on: 23 June 2022; Accepted on: 25 July 2022; Published on: 31 August 2022

ABSTRACT

Objective: To study the use of serial ultrasound gastric residual volume (GRV) measurements in predicting feed intolerance in critically ill patients.

Patients and methods: This study was conducted in various intensive care units (ICUs) of All India Institute of Medical Sciences, New Delhi. Forty-three critically ill patients aged more than 18 years were studied for a total of 130 enteral feeding days. Gastric residual volume was obtained by calculating the antral cross-sectional area (CSA), which is the product of anteroposterior (AP) and craniocaudal (CC) diameters of gastric antrum obtained using ultrasound in the right lateral decubitus position. A baseline measurement was done before the initiation of the enteral feed and termed GRV0, the ultrasound scanning was repeated every 1 hour for the first 4 hours and termed GRV1, GRV2, GRV3, and GRV4, respectively, and the patients were watched for feed intolerance. The receiver operating characteristic (ROC) curves were constructed to correlate the GRV at each time with feed intolerance.

Results: The data from 43 medical and surgical critically ill patients were analyzed. Out of 130 feeding days, 13 were noted to be feed intolerant. Gastric residual volume at the end of the fourth hour of feed, that is, GRV4 was the best predictor of feed intolerance with 99.3% area under the curve (AUROC), sensitivity of 99%, specificity of 99.3%, and 95% CI, 0.89–0.98 followed by GRV3, with AUROC of 96% and sensitivity and specificity of 92.3 and 96%, respectively, with 95% CI, 0.92–0.99.

Keywords: Enteral feed intolerance, Gastric residual volume, Intensive care, Intensive care unit, Nasogastric feeding, Ultrasound.

Indian Journal of Critical Care Medicine (2022): 10.5005/jp-journals-10071-24296

INTRODUCTION

Nutrition in patients admitted to the ICU is an essential treatment. Enteral nutrition (EN) is superior to parenteral nutrition (PN) in patients admitted to the ICU.

The usual practice of initiating enteral feeding in patients is to use nasogastric (NG) or orogastric (OG) tubes. After confirming the correct position clinically and radiologically, a tailored amount of feed for a particular patient is infused into these tubes with an infusion pump or an IV drip set. Before starting these feeds, the stomach is emptied by suctioning the contents. The volume of the suctioned contents is considered proportional to the GRV. Depending on the volume of the aspirated content, the decision to start enteral feed is made. It is already known that, in an ICU, this cut-off value is 250 mL. However, as per the recent guidelines in some ICUs, this has been changed to 500 mL.¹

The recent American Society of Enteral and Parenteral Nutrition (ASPEN) 2016 guidelines and European Society of Enteral and Parenteral Nutrition (ESPEN) 2017 guidelines recommend that intensivists diagnose feed intolerance clinically and do not monitor GRV by aspirating the feed. However, other experts in the field partially disagree with this and opine that the GRV is not a Dead Marker.² However, intensivists stress that if the GRV is not monitored, then it would increase the risk of aspirating the gastric contents leading to morbidity and mortality in these patients.^{3–7} A recent study by Taskin et al. has concluded that the ultrasonographic measurement of gastric antral CSA can reliably estimate GRV in critically ill patients receiving EN.⁸

^{1,3,4,7,10,11}Department of Anaesthesiology, Critical Care and Pain Medicine, All India Institute of Medical Sciences, New Delhi, India

²Department of Anesthesiology, Washington University in St. Louis, St. Louis, Missouri, United States of America

⁵Department of Critical Care, All India Institute of Medical Sciences, New Delhi, India

⁶Department of Critical and Intensive Care, Jai Prakash Narayan Apex Trauma Center, All India Institute of Medical Sciences, New Delhi, India

^{8,9}Department of Radiodiagnosis and Interventional Radiology, All India Institute of Medical Sciences, New Delhi, India

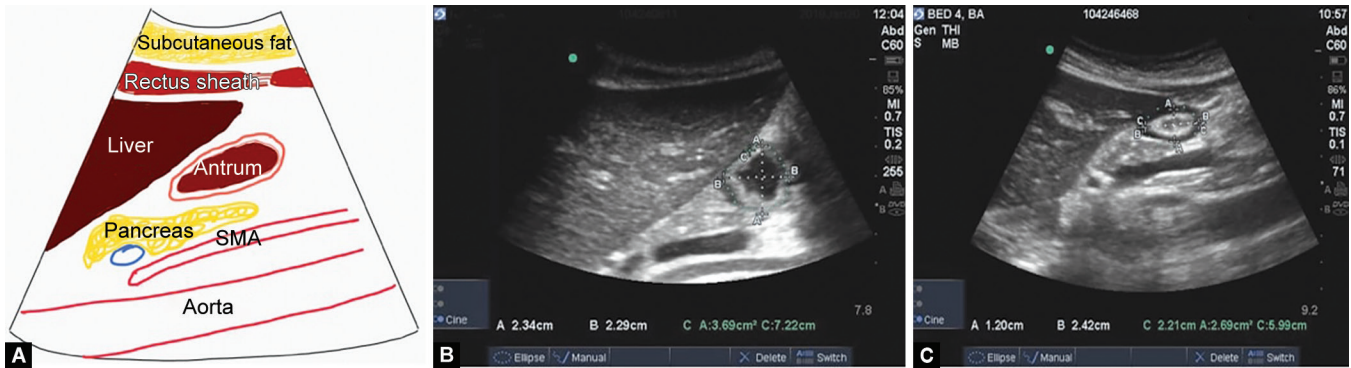
Corresponding Author: Manpreet Kaur, Department of Anaesthesiology, Critical Care and Pain Medicine, All India Institute of Medical Sciences, New Delhi, India, Phone: +91 018102255099, e-mail: manpreetkaurrajpal@yahoo.com

How to cite this article: Ankalagi B, Singh PM, Rewari V, Ramachandran R, Aggarwal R, Soni KD, et al. Serial Ultrasonographic-measurement of Gastric Residual Volume in Critically Ill Patients for Prediction of Gastric Tube Feed Intolerance. *Indian J Crit Care Med* 2022;26(9):987–992.

Source of support: Nil

Conflict of interest: None

Recently, perioperative measurement of residual gastric volume using ultrasound to assess the risk of aspiration has become popular as ultrasound is accessible bedside in most hospitals.¹ The utility of this technique in critically ill patients admitted in ICUs is feasible



Figs 1A to C: Schematic diagram and ultrasound images of the gastric antrum

and reliable tool to assess the aspiration risk.^{8,9} A study by Arzola et al. also showed that mastering this technique requires only 33 scans by a trained sonologist; thus, it is easy to learn.¹⁰ However, despite its promising role, it has been underutilized.

Hence, there exists a gap between what is proposed in ASPEN guidelines and the upcoming utility of gastric ultrasonography to look for residual gastric volume. After addressing these clinical problems and studies on ultrasound measured gastric residual volume (uGRV), this study was initiated to assess the GRV of critically ill patients using ultrasound and to correlate it with the feed intolerance.

OBJECTIVE

This study aimed to use ultrasound as a tool to correlate tolerance to enteral tube feed in medical or surgical ICU patients. The main objective of this study was to compare the uGRV in critically ill medical or surgical patients with tolerance or intolerance of enteral feed and to assess the same as a tool in predicting intolerance early.

PATIENTS AND METHODS

It was a prospective interventional study. Institutional ethics committee approval was obtained on 31 January 2018 (No. IECPG-642/31.01.2018), and the study was registered under the Clinical Trials Registry Indian Council of Medical Research and National Institute of Medical Statistics (ICMR–NIMS) Clinical Trial Registry of India (CTRI) No. CTRI/2018/06/014482. The study was conducted in the various ICUs at All India Institute of Medical Sciences, New Delhi, India during the period of February 2018 to October 2019 over a span of 18 months. The inclusion criteria for patients were a minimum of 18 years of age; patients deemed fit for the initiation of enteral feed as per the ICU protocols and decision of the attending physician, ICU length of stay of at least 2 days, and critical surgical patients in whom the GI tract was not operated. The exclusion criteria were patient refusal, patients with primary gastrointestinal tract pathology, patients on high-vasopressor support (NorAdr of ≥ 5 $\mu\text{g}/\text{min}$ or more than one vasopressor), patients on nasojejunal feeds, and pregnancy.

Written informed consent was obtained from all patients’ guardians or relatives for inclusion in the study. An NG or an OG tube was inserted, and its correct position was confirmed clinically and with abdominal radiography. As per the ICU protocol, before initiating the tailored enteral feed (according to the patient’s body weight and nutritional requirements), the gastric tube was suctioned to aspirate all gastric contents. The standard enteral feed

prepared by the hospital as prescribed by the ICU consultant was initiated, that is, 30 kcal/kg of the patients’ body weight, which was given as an infusion over 16 hours. This was followed by an 8-hour feed-free period (standard practice in the ICU), and the enteral feed was restarted the next morning after suctioning the gastric tube as described earlier.

It is known that every time the enteral feed was initiated, each patient had an equal chance of developing feed intolerance; thus, if the patient met the inclusion criteria on a given day, then that patient was re-recruited into the study every time enteral feed was initiated. The patient could be studied on different days if the feed was withheld. The reasons for withholding the feed were as follows: Hemodynamic instability requiring a high dose of vasopressors or signs and symptoms of feed intolerance.

Before starting EN, the NG/OG tube was aspirated, and the first, that is, GRV₀ was recorded after all contents had been aspirated. All ultrasound examinations were performed using the ultrasound machine, Sonosite Edge. Ultrasound examinations were performed with a low frequency (2–5 MHz) curvilinear-array transducer (C60) in the right lateral decubitus position, and the probe was placed in the parasagittal plane in the epigastrium. The gastric antrum was superficially identified between the left lobe of the liver anteriorly and the pancreas, superior mesenteric artery (SMA), and aorta posteriorly in a sagittal or parasagittal scanning plane in the epigastrium to obtain a transverse view of the antrum avoiding oblique images (Fig. 1A). Three consecutive still images were obtained at each time and labeled. The two perpendicular diameters, the AP diameter, and the CC diameter were noted (from serosa to serosa), and at each time, the mean diameter was calculated to form all three images.

Assuming the antrum to be an elliptical structure, the gastric antral CSA was calculated using the following formula:

$$CSA = AP \times CC \times (\pi/4)$$

where CSA is CSA of the antrum, AP is anteroposterior diameter, CC is craniocaudal diameter, and π is a constant. Then the gastric volumes were calculated using the following formula recommended by Perlas et al. at each time.¹¹

$$GRV = 27.0 + 14.6 \times \text{Antral CSA (in cm}^2) - 1.28 \times \text{Age (in years)}$$

where 27.0, 14.6, and 1.28 are constants.

The gastric tube was suctioned before initiating the feed. At the same time, after suctioning the gastric tube, the basal GRV (GRV₀) was measured with ultrasound by the above-mentioned method



Table 1: Demographic parameters and statistical variables

Parameter	Feed tolerant patients (n = 117)	Feed intolerance group (n = 13)	p-value
Age (years ± SD)	37.5 ± 16.6	36.7 ± 15.8	0.862
Male	71	7	0.628
Female	46	6	
Weight (kg ± SD)	60.5 ± 14.2	56.0 ± 9.9	0.259
Rate of feed (mL/hour ± SD)	94.6 ± 22.2	87.5 ± 15.5	0.260
GRV ₁ (mL ± SD)	27.8 ± 8	83.5 ± 26	<0.012
GRV ₂ (mL ± SD)	60.9 ± 35.4	118.6 ± 28.8	<0.014
GRV ₃ (mL ± SD)	106.9 ± 97.4	176.4 ± 20.1	<0.008
GRV ₄ (mL ± SD)	149.0 ± 33.8	249.0 ± 22.0	<0.09
GRV ₁ %	30	95	–
GRV ₂ %	32	68	–
GRV ₃ %	37	67	–
GRV ₄ %	39	71	–

GRV₁, gastric residual volume at the end of 1 hour; GRV₂, gastric residual volume at the end of 2 hours; GRV₃, gastric residual volume at the end of 3 hours; GRV₄, gastric residual volume at the end of 4 hours; GRV₁%, percentage of feed remaining in the stomach at the end of 1 hour of feed; GRV₂%, percentage of feed remaining in the stomach at the end of 2 hours of feed; GRV₃%, percentage of feed remaining in the stomach at the end of 3 hours of feed; GRV₄%, percentage of feed remaining in the stomach at the end of 4 hours of feed; SD, standard deviation

noted and labelled as GRV₀. The ultrasound scans were repeated hourly by and value GRV₁, GRV₂, GRV₃, and GRV₄ at 1, 2, 3, and 4 hours, respectively (Fig. 1).

Feed intolerance was defined clinically by symptoms such as abdominal pain, discomfort, abdominal distention, regurgitation, or vomiting. If any patient had developed feed intolerance, the feed was withheld, and the patient was labelled feed intolerant. The feed was restarted after the clinician wanted to do so (which was usually after a gap of 12–24 hours as per the decision treating physician). During the entire study, the treating physicians were blinded to the results of the study.

The initial 35 scans were performed by the radiologist while simultaneously teaching the technique to the principal investigator, and later the scans were performed by the principal investigator of the study.

Statistical Analysis

Due to the paucity of studies, we conducted this pilot study. All statistical analyses were done using STATA 14 software (StataCorp. 2015, Stata Statistical Software: Release 14, College Station, TX: StataCorp LP). The data following normal distribution were compared with an independent *t*-test and, if not following a normal distribution with the Wilcoxon rank test. The ROC curve analysis was used to assess the utility by assessing the discriminant ability of the parameter at each time. Also, *p* < 0.05 was considered statistically significant.

Observations and Results

This study was performed on the patients who were getting treated at the various ICUs of All India Institute of Sciences, New Delhi. A total of 43 patients were recruited, and these 43 patients were studied for a total of 130 sessions or 130 feeding days, as few patients recovered and were shifted out of the ICUs and others conditions worsened and were no longer eligible under inclusion criteria. Each session consisted of five scans at 1-hour interval (GRV₀ to GRV₄). If a patient showed no signs of feed intolerance, he/she was included in the study again on the next day as it is not uncommon for patients in ICU to develop enteral feed intolerance whenever their clinical condition worsens. All the patients were ventilated as

they were shifted out of the ICU as soon as they got extubated or deteriorated to the point where they did not fit the inclusion criteria for the study. None of them received the vasopressors—either their condition got resolved or they deteriorated so much that they had to be excluded from the study.

Feed intolerance was encountered on 13 occasions out of a total of 130 episodes. After all these 13 episodes, the patients in whom they were seen never achieved the criteria for re-evaluation. The demographic details and statistical variables of the recruited patients were as shown in Table 1.

The predictive ability of GRV measured at each time was analyzed by the ROC curve, which showed that the AUROC was highest for GRV₄, GRV₃, GRV₁, and GRV₂, respectively, and the same is tabulated in Table 2 and depicted in Figure 2.

The ROC analysis yielded the cut-off values for each GRV at each time and feed predictive intolerance ability of each GRV measured at different time.

DISCUSSION

Most of the patients in an ICU need adequate nutrition and, this is provided by enteral or parenteral route. The former is the preferred route as it has been shown that patients receiving enteral feeds have better outcomes than those receiving the parenteral feed.¹

This study involved all patients who needed enteral feed in ICUs and who could be included according to the inclusion criteria for the study. After starting the enteral feed, the GRV was measured at the end of the first, second, third, and fourth hours, using the ultrasound method as described by Perlas A et al.¹¹

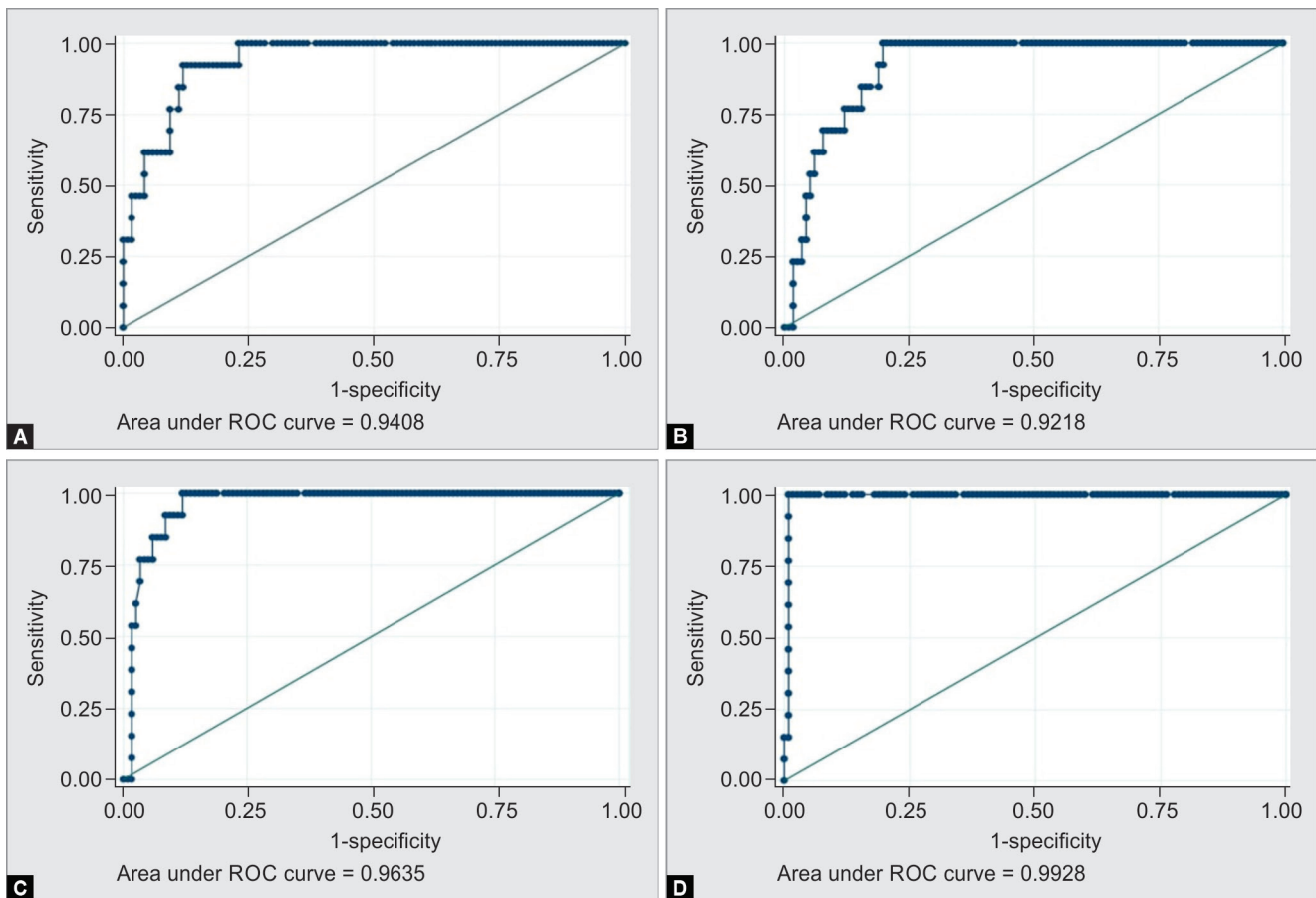
The GRV can be estimated by the bedside either by aspirating the gastric contents or by the use of an ultrasound. The disadvantages of aspirating gastric contents are suboptimal nutritional delivery and clogging of the tube, which can further lead to the possibility of nasal trauma and the risk of aspirations.¹²

The advantages of the GRV measurement using ultrasound are as follows: It is a non-invasive bedside test, and it provides real-time GRV assessment without interrupting the feed. Presently, most of the ICUs have an ultrasound machine available bedside as it has a widespread application in the ICU. The recent studies have

Table 2: Results from the receiver operating characteristic curve analysis in the feed intolerance group of patients (n = 13)

Ultrasound parameter	Cut-off value (in mL)	SN	SP	AUROC (%)	p-value
GRV ₁	49.9	92.3	88.0	94.1	0.021
GRV ₂	86.8	84.6	83.7	92.2	0.042
GRV ₃	148.0	92.3	91.4	96.4	<0.012
GRV ₄	216.7	100	99.1	99.3	<0.014

AUROC, area under receiving operating characteristic curve; GRV₁, gastric residual volume at the end of 1 hour; GRV₂, gastric residual volume at the end of 2 hours; GRV₃, gastric residual volume at the end of 3 hours; GRV₄, gastric residual volume at the end of 4 hours; p <0.05 is statistically significant; SN, sensitivity; SP, specificity



Figs 2A to D: Receiver operating characteristic curve showing the predictive ability of the GRV cut-off values at each time

highlighted the fact that ultrasound measured GRV has good inter-observer reliability.⁷

This study endeavored to use serial ultrasound scans to measure GRV to predict the intolerance of enteral feed. As per our literature search, the GRV, as measured by ultrasound, has not been used for the prediction of tolerance or outcome of enteral feed in patients admitted in a surgical or medical ICU.

Some of the recent studies have pointed out that cut-off value of the aspirated GRV to 250 mL and discontinuing the feed can lead to suboptimal nutrition delivery in critically ill patients who are already at the risk of malnutrition and catabolism. The recent studies also pointed out that by increasing the cut-off value of the aspirated GRV from 250 mL to 500 mL, there were no significant untoward effects such as aspiration pneumonia or enteral feed intolerance, but it enhanced the recovery of the patient by providing adequate nutrition.⁶

The acceptance of enteral feed is a critical feature in the overall care of the patients in ICU, and most of the time, it is ascertained by clinical signs and symptoms of feed intolerance (abdominal distension, abdominal pain, vomiting, regurgitation, or a high volume of gastric aspirations). The definition of feed intolerance is clinically determined by the attending intensivist of ICU which is subjective and may be different amongst observers. Recently, ultrasound has been used to measure the gastric volume in perioperative as well as ICU patients, which is considered as a surrogate marker of the gastric contents.^{7,8}

The recent ASPEN 2016 guidelines and ESPEN 2017 guidelines recommend that intensivists diagnose feed intolerance clinically and not monitor GRV by aspirating the feed. However, the other experts in the field partially disagree with this and opine that GRV is a useful marker.⁹ However, some of the intensivists stress the fact that if the GRV is not monitored, then it would increase the

risk of patients aspirating the gastric contents leading to morbidity and mortality in these patients.¹⁰ Advantage of predicting feed intolerance early is that if we can predict feed intolerance early, we can initiate steps to prevent aspiration and meet the nutritional requirements of critically ill patients.

The gold standard for GRV monitoring is scintigraphy which might not be practically feasible as a bedside test. It has been reported that the ultrasound measured GRV is a better marker than gastric tube aspirate. Both values have been correlated with each other, and the ultrasound measured GRV also has a good correlation with the gold standard scintigraphy, in another study where they correlated the gastric antral area with aspirated feed. The study concluded that the gastric antral area had a positive correlation with the aspirate from the gastric tube.^{7,13,14}

In the other studies, the GRV measured at the end of 6–24 hours ranged 250–1,000 mL in the feed intolerant patients.¹¹ Furthermore, the GRV measured after 6–8 hours of fasting in preoperative patients scheduled for elective procedures ranged 0–80 mL.^{11,15,16}

The ASPEN guidelines recommend not to aspirate the gastric contents and to monitor intolerance only clinically. However, some experts feel that GRV needs to be monitored and our study bridges the gap by non-invasive monitoring of GRV using ultrasound without compromising the patients' nutrition intake. Our study found that the GRV at the end of the third and fourth hours of feeding could predict whether a patient would develop feed intolerance. As per our knowledge and literature search, there are no similar studies where the percentage of total infused feed at regular intervals has been studied. Earlier studies have documented only the gastric residual aspirates after a fasting period of 6–24 hours. The above values cannot be compared with those seen in this study.

Limitations

There were limitations of this study. This study was an observational study, and we included a heterogeneous group of critically ill patients, GRV was measured only for initial 4 hours (if the same was continued for up to 6 hours or more, it might have given better results but it has to be kept in mind more frequent observations can be too cumbersome). Another limitation was that USG GRV was measured in lateral position each hour which may become practically cumbersome in the ICU setting where there is less staff. However, it was not a problem in our ICU. Including main indication of ICU admission, severity of illness score, use of ICU therapies like mechanical ventilation or dialysis or vasopressor as subset of data can yield further better results and can be planned in further replica studies. The operational definition of enteral feed intolerance is as per the treating intensivist (as we did not want to interfere with the standard treatment protocol at the ICUs). We have used the right lateral decubitus position which may be difficult in some critically ill patients as compared to the 30° head-up supine position. The lateral decubitus position was used only for a minute or two that too when the patient was stable enough to do so, and all the measurements were done in this position only as per the protocol. Some of the patients were positioned in lateral position even prior to the measurement time by the ICU team as per the ICU protocol intended for the prevention of pressure ulcers or bed sores. The study is valid only in patients receiving OG/NG tube feed with continuous infusion. The sample size of the study was small (as most of the ICU patients were excluded due to the strict exclusion criteria).

CONCLUSION

Serial ultrasonographic measurement of GRV can be used in critically ill patients for prediction of gastric tube feed intolerance in medical or surgical ICU patients receiving enteral tube feed. Ultrasound can be used to measure GRV to predict feed intolerance with a sensitivity of 92% and specificity of 96%, (3 hours) and with a sensitivity of 100% and specificity 99%, and AUROC of 99.3% (4 hours). Hence, in critically ill patients, receiving gastric tube feed through continuous infusion, serial ultrasonographic measurement of GRV identifies feed intolerance with good sensitivity and specificity.

ORCID

Basavaraj Ankalagi  <https://orcid.org/0000-0001-9513-755X>

Preet Mohinder Singh  <https://orcid.org/0000-0001-7642-529X>

Vimi Rewari  <https://orcid.org/0000-0001-9800-1367>

Rashmi Ramachandran  <https://orcid.org/0000-0001-6083-7513>

Richa Aggarwal  <https://orcid.org/0000-0002-4531-2759>

Kapil Dev Soni  <https://orcid.org/0000-0003-1214-4119>

Debashish Das  <https://orcid.org/0000-0003-2851-679X>

Kumble Seetharama Madhusudhan  <https://orcid.org/0000-0001-8806-2625>

Deep Narayan Srivastava  <https://orcid.org/0000-0002-3041-0735>

Manpreet Kaur  <https://orcid.org/0000-0003-3069-1562>

Anjan Trikha  <https://orcid.org/0000-0002-6001-8486>

REFERENCES

- McClave SA, Taylor BE, Martindale RG, Warren MM, Johnson DR, Braunschweig C, et al. Guidelines for the provision and assessment of nutrition support therapy in the adult critically ill patient: Society of Critical Care Medicine (SCCM) and American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.). *J Parenter Enteral Nutr* 2016;40(2):159–211. DOI: 10.1177/0148607115621863.
- Elke G, Felbinger TW, Heyland DK. Gastric residual volume in critically ill patients: a dead marker or still alive? *Nutr Clin Pract* 2015;30(1): 59–71. DOI: 10.1177/0884533614562841.
- Dalhoff K, Abele-Horn M, Andreas S, Bauer T, von Baum H, Deja M, et al. [Epidemiology, diagnosis and treatment of adult patients with nosocomial pneumonia. S-3 Guideline of the German Society for Anaesthesiology and Intensive Care Medicine, the German Society for Infectious Diseases, the German Society for Hygiene and Microbiology, the German Respiratory Society and the Paul-Ehrlich-Society for Chemotherapy]. *Pneumologie* 2021;66(12):707–765. In German. DOI: 10.1055/s-0032-1325924.
- Nseir S, Zerimech F, Jaillette E, Artru F, Balduyck M. Microaspiration in intubated critically ill patients: diagnosis and prevention. *Infect Disord Drug Targets* 2011;11(4):413–423. DOI: 10.2174/187152611796504827.
- McClave SA, DeMeo MT, DeLegge MH, DiSario JA, Heyland DK, Maloney JP, et al. North American Summit on Aspiration in the Critically Ill Patient: consensus statement. *J Parenter Enteral Nutr* 2002;26:S80–S85. DOI: 10.1177/014860710202600613.
- Hsu CW, Sun SF, Lee DL, Lin SL, Wong KF, Huang HH, et al. Impact of disease severity on gastric residual volume in critical patients. *World J Gastroenterol* 2011;17(15):2007–2012. DOI: 10.3748/wjg.v17.i15.2007.
- Kruisselbrink R, Arzola C, Endersby R, Tse C, Chan V, Perlas A. Intra- and interrater reliability of ultrasound assessment of gastric volume. *Anesthesiology* 2014;121:46–51. DOI: 10.1097/ALN.000000000000193.
- Taskin G, Inal V, Yamanel L. Does ultrasonographic assessment of gastric antrum correlate with gastric residual volume in critically ill

- patients? A prospective observational study. *J Clin Monit Comput* 2021;35(4):923–929. DOI: 10.1007/s10877-021-00707-y.
9. Hamada SR, Garcon P, Ronot M, Kerever S, Paugam–Burtz C, Mantz J. Ultrasound assessment of gastric volume in critically ill patients. *Intensive Care Med* 2014;40(7):965–972. DOI: 10.1007/s00134-014-3320-x.
 10. Arzola C, Carvalho JCA, Cubillos J, Ye XY, Perlas A. Anesthesiologists' learning curves for bedside qualitative ultrasound assessment of gastric content: a cohort study. *Can J Anaesth* 2013;60:771–779. DOI: 10.1007/s12630-013-9974-y.
 11. Perlas A, Mitsakakis N, Liu L, Cino M, Haldipur N, Davis L, et al. Validation of a mathematical model for ultrasound assessment of gastric volume by gastroscopic examination. *Anesth Analg* 2013;116:357–363. DOI: 10.1213/ANE.0b013e318274fc19.
 12. Moreira TV, McQuiggan M. Methods for the assessment of gastric emptying in critically ill, enterally fed adults. *Nutr Clin Pract* 2009;24(2):261–273. DOI: 10.1177/0884533609332176.
 13. Irvine EJ, Tougas G, Lappalainen R, Bathurst NC. Reliability and interobserver variability of ultrasonographic measurement of gastric emptying rate. *Dig Dis Sci* 1993;38(5):803–810. DOI: 10.1007/BF01295904.
 14. Hveem K, Jones KL, Chatterton BE, Horowitz M. Scintigraphic measurement of gastric emptying and ultrasonographic assessment of antral area: relation to appetite. *Gut* 1996;38(6):816–821. DOI: 10.1136/gut.38.6.816.
 15. van de Putte P, Perlas A. Gastric sonography in the severely obese surgical patient: a feasibility study. *Anesth Analg* 2014;119(5):1105–1110. DOI: 10.1213/ANE.0000000000000373.
 16. van de Putte P, van Hoonacker J, Perlas A. Gastric ultrasound to guide anesthetic management in elective surgical patients non-compliant with fasting instructions: a retrospective cohort study. *Minerva Anesthesiol* 2018;84(7):787–795. DOI: 10.23736/S0375-9393.17.12305-9.