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Gastric Residual Volume measurement in UK paediatric intensive care units: a survey of practice

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140 character tweet: The routine measurement of gastric residual volume to guide enteral feeding is common in UK PICUs, despite limited evidence and a lack of guidance

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Gastric Residual Volume measurement in UK pediatric intensive care units: a survey of practice

Abstract

Objective: Despite little evidence, the practice of routine measurement of gastric residual volume to guide both the initiation and delivery of enteral feeding in pediatric intensive care units is widespread internationally. In light of increased scrutiny of the evidence surrounding this practice, and as part of a trial feasibility study, we aimed to determine enteral feeding and Gastric Residual Volume (GRV) measurement practices in United Kingdom (UK) Pediatric Intensive Care Units (PICUs).

Design: An online survey to 27 United Kingdom Pediatric Intensive Care Units

Setting: United Kingdom Pediatric Intensive Care Units

Subjects: A clinical nurse, senior doctor and dietician were invited to collaboratively complete one survey per PICU and send a copy of their unit guidelines on enteral feeding and GRV.

Interventions: None

Main Results: 24/27 (89%) units approached completed the survey. Twenty-three units (95.8% 23/24) had written feeding guidelines and 19 units (19/23 83%) sent their guidelines for review. More units fed continuously (15/24 62%) than intermittently (9/24 37%) via the gastric route as their primary feeding method. All but one PICU routinely measured GRV, regardless of the method of feeding. Eighteen units had an agreed definition of feed tolerance, and all these included GRV. GRV thresholds for feed tolerance were either volume based (ml/kg body weight) (11/21 52%) or a percentage of the volume of feed administered (6/21 29%). Yet only a third of units provided guidance about the technique of GRV measurement.

Conclusions: Routine GRV measurement is part of standard practice in UK PICUs, with little guidance provided about the technique which may impact the accuracy of GRV. All PICUs that defined feed tolerance included GRV in the definition. This is important to know when proposing a standard practice arm of any future trial of no routine GRV measurement in critically ill children.

INTRODUCTION

Routine measurement of gastric residual volume (GRV) to direct and guide enteral feeding and define feed intolerance lacks evidence and is increasingly being questioned in pediatric intensive care units (PICUs) (1,2,3). Despite the paucity of evidence underpinning this practice, the practice is widespread internationally (4,5,6). Surveys have shown that this practice varies across countries (5). Some units do not measure GRV with seemingly no adverse effects, providing further strength to examine this historical practice in more detail (5). GRV is defined as the aspiration of the entire stomach contents, with a view to assess feeding tolerance, both in terms of assessing the volume and often the color of the aspirate, it is not the aspiration of a small amount of fluid for pH testing to confirm feeding tube position. PICU clinicians' fear of a large GRV stems from the fear of vomiting and potential pulmonary aspiration (3). However, this risk has never been quantified either in children or adults. Furthermore, this measurement is not accurate (7, 8, 9) and evidence shows it is not a useful surrogate marker for delayed gastric emptying in critically ill children (10). In this study, we aimed to describe current practice around GRV measurement specifically. In addition, we sought to delineate enteral feeding practices in UK PICUs in relation to GRV, to develop a 'control arm' of a future trial to compare no routine GRV measurement (the intervention) to routine GRV measurement.

MATERIALS AND METHODS

An online survey, was developed by the research team to explore current practices around GRV measurement and general enteral feeding practices in PICUs. The aim was to use survey findings alongside a review of local PICU guidelines to inform the design of a future trial. The survey consisted of closed questions (tick-box responses), two ranked questions, 18 open-ended questions, and options for free text responses where the response was 'other' to closed questions. A pilot was conducted involving 10 staff (doctors, dieticians, nurses) for face validity. Minor wording

adjustments were made to improve clarity, then the 35 item survey (Supplementary Appendix) was tested again within the study team.

The survey focused on three domains: general enteral feeding and nutrition practices in the respondents' unit, the GRV measurement technique used in the respondents' unit, and clinical management in response to GRV. The survey invitation asked for a senior doctor (attending), a clinical nurse and a dietician to complete the survey collaboratively and submit one response per unit, and to upload any written guidelines or protocols. Unit name was collected to target non-responders and check for duplicates; three reminders were sent to maximise response rates. Our target response rate was 70%.

Twenty-seven UK PICUs were approached: these are units that admit children for at least 24 hours of intensive care, and who are part of the national research network (PICS-SG). During May and June 2018, each unit was contacted via professional networks (The Pediatric Intensive Care Society (PICS) and the British Pediatric Dietetic Association (BPDA Critical Care Group)), and sent a link to the survey via e-mail. Study data were collected and managed using REDCap electronic data capture tools hosted at the University of Liverpool (11). Data were summarised using descriptive statistics for quantitative data and thematic analysis for qualitative free text data (12). Following this, the PICU guidelines were reviewed and summarized. Ethical approval for the study was provided by the University of the West of England (Reference: HAS.18.04.144) and the Pediatric Intensive Care Study Group (PICS-SG) additionally approved the survey.

RESULTS

Twenty-four of 27 (89%) UK PICUs completed the survey. These were a mixture of general PICUs (13/24 54%), mixed cardiac surgical and general PICUs (7/24 29%) and standalone cardiac ICUs (4/24 17%). Collective unit responses were completed by senior doctors (22/24 92%); nurses (23/24 96%) and dieticians (23/24 96%). Almost all (23/24 96%) responding PICUs reported written guidance around enteral feeding and most of these (19/23 83%) sent their guidelines. All responding

PICUs undertook some nutritional assessment at PICU admission (Table 1). Most PICUs (15/24 63%) used the Schofield equation to predict energy requirements and aimed to achieve full energy targets within 48-72 hours. Over half (14/24 58%) of PICUs had a target time to initiate enteral feeding, and for half (7/14 50%) of these this was within 6 hours of admission (total range 2 – 24 hours). Enteral feeding was more commonly delivered continuously (15/24 62%) than intermittently (9/24 37%) via the gastric route, which was the preferred route. Continuous feeding was mostly delivered over 24 hours a day (9/15 60%) or over 20 hours a day (5/15 33%). Where feeding was by intermittent bolus, this was predominantly every two hours (6/9 67%). Most units (15/24 62%) reported using standard rigid gastric tubes, with 8/24 (33%) using soft silicone tubes as their standard feeding tube.

Most PICUs (18/24 75%) defined feed tolerance/intolerance in their guidance, and of these, definitions included GRV (18/18 100%), vomiting (12/18 67%), diarrhea (9/18 50%) and abdominal appearance (8/18 44%). All but one (23/24 96%) responding PICU measured GRV routinely as part of their standard practice, and none reported that the policy was different for invasively ventilated versus non-ventilated children. The frequency of GRV measurement was most commonly reported as 4-hourly (18/24 75%) in the survey (Table 2) and (15/19 79%) in the unit guidelines (Table 3); or before each bolus feed. Yet, most PICUs (16/24 67%) reported little guidance around the technique of measuring GRV. Only 71% (17/24) of responding units indicated a specific syringe size to use with GRV measurement (but this was rarely written in their guidelines). Where this was specified, this was most commonly (10/17 59%) a 50-60ml syringe. Most units (15/24 62%) reported that the feeding method (continuous or intermittent) did not influence the frequency of GRV measurement. Yet, for almost all units using bolus gastric feeds GRV was reported to be measured, compared to at a fixed time period for continuous feeds. Half of responding units (12/24 50%) reported that size of the child (>40-50kg) did not affect the frequency of GRV measurement.

Almost all (21/24 87%) responding units reported GRV was the main indicator to withhold enteral feeding. The decision to withhold feeds was determined most frequently by a maximum

volume in ml/kg body weight (11/21 52%). Twenty-nine percent (6/21) of units reported using a maximum percentage of volume of feed given, but this was higher (8/19 42%) in the unit guidelines (Table 3). The volume above which feeds were withheld was reported as 5ml/kg by 50% (11/21) of units in the survey and 58% (11/19) in the guidelines. In the 7 units whose guidelines stipulated an upper absolute level (for children over 40-50Kg), this was most frequently 200ml (5/7 71%). Of the 6 guidelines that used a percentage of volume of feed given in previous hours, this varied from more than 50% of feed given in the previous 4 hours, to 100% of the feed given in the previous 2-6 hours. A percentage of the volume of the previous 4 hours of feed given was used in 5/19 (26%) of the guidelines (Table 3). More than half (14/24 58%) of responding units reported that they did not vary the threshold according to size of children.

The decision to withhold enteral feeds was generally made regarding both the amount of GRV and its color; 58% (14/24) of units rated the importance of the amount of GRV as 'high' or' 'very high', and 62% (15/24) units rating the importance of the color of the GRV as 'high' or' 'very high'. Guideline analysis and free text responses all cited abnormal color aspirates being green (bilious), red (bloody) or brown (fecal) in appearance, and even if the volume was not large, aspirates of this appearance would be discarded and indicate the withholding of feeds.

Most (15/24 62%) units in the survey reported returning GRV. None reporting that GRVs were routinely discarded, but that this was dependant on individual patient factors and aspirate appearance. However, most guidelines required (84% 16/19) return the GRV in all patients unless it was abnormal in appearance. In response to obtaining 'high' GRVs, PICUs reported their actions by free text and then actions were ranked by frequency in the survey. Qualitative responses indicated that for the majority of PICUs, in the first instance, enteral feeds would be withheld for a period of time (commonly 2 hours) and GRV reassessed. After this, actions ranked by order of priority were most commonly: 1) changing the feeding method from bolus to continuous feeds, 2) changing to post-pyloric feeding and/or changing the feed formula, 3) adding prokinetics and persisting with

gastric feeding and lastly 4) stopping enteral feeds and commencing parenteral nutrition. Guidelines analysis also revealed that for 79% (15/19) units, the initial action in response to a large GRV was to stop feeds for a period of time and re-check the GRV (Table 3).

Guideline analysis (Table 3) revealed six units had defined levels of abdominal risk for enteral feeding of children. Five out of these six units admitted cardiac surgical neonates (5/6 83%) and defined low and high-risk abdomens in their protocols based on the patient profile. Defining features of a high risk abdomen included infants with hypoplastic left heart syndrome, aortic arch abnormalities, shunts and duct-dependant circulations, gut concerns including confirmed necrotizing enterocolitis (NEC) in the last 4 weeks, high vasopressor support, high lactate concentrations, low somatic Near Infrared Spectroscopy (NIRS) and after cardiac arrest and Extra Corporeal Life Support (ECLS). In all situations, even where different feeding regimes were specified in relation to risk, both protocols (for low and high risk) still used routine GRV measurement, but the rate of feed delivery and the speed of advancement was much slower in the high-risk patients.

DISCUSSION

To our knowledge, this is the first study to specifically examine the practice of GRV measurement in the context of enteral feeding practices in critically ill children. Increasingly, the evidence and assumptions underpinning this practice are being questioned, with the view that this practice may lead to the unnecessary withholding of enteral nutrition (13). Simulation studies (7,8) have shown that the measurement of GRV itself is inaccurate. The amount obtained is markedly affected by a number of factors: the syringe size used to aspirate, the pressure used to aspirate, the viscosity of the solution being aspirated, the type of gastric tube (material and size), the position of the tube tip in the stomach, and in a further study in neonates, the position of the child themselves (9). Smaller syringes generate greater negative pressure than larger ones, and soft silicone feeding tubes collapse upon aspiration, reducing the volume obtained making the value meaningless. Of note, in our study 33% of units reported using soft silicone gastric tubes, likely making the amount of

aspirate obtained inaccurate – even though the GRV results obtained in these units were used to guide feeding. Further inaccuracy is introduced through the variety of syringe sizes reportedly used to aspirate the gastric tube.

Therefore, there are valid questions about the accuracy of the amount of GRV obtained. When decision-making is based on volume alone, clinicians often fail to consider that GRV does not just reflect feed administered, but also large gastric secretions which are physiologically produced during the digestion process (3). Secondly, many clinicians use GRV as a surrogate marker for delayed gastric emptying (GE) (3,4). However, a recent prospective study in 20 critically ill children, assessed GE using paracetamol absorption monitoring and clearance, and found that GRV did not predict GE (10). Children with delayed GE had both high, normal and low GRVs. Thirdly, once GRV is obtained, a number of arbitrarily defined thresholds are applied to determine the 'acceptability' of this volume, and thus define both tolerance and intolerance, based on no sound evidence (2). Most commonly, in half of units, a threshold of 5ml/kg body weight was used. Considering that UK PICUs admit children aged 0 to 17 years, with a range of weights, from around 2kg to more than 100Kg, this threshold is not helpful, and no study has yet determined any optimal threshold. The majority of remaining units used a percentage of the amount of feed delivered in the previous hours as the threshold for tolerance. There is some common sense in this approach, but again it does not account for endogenous gastric secretions or the potential inaccuracy of the measurement itself.

PICU clinicians fear vomiting and aspiration (3) leading to Ventilator Associated Pneumonia (VAP), when there is a high GRV, but yet again this risk has never been quantified. A small pediatric observational study between two PICUs, one who measured GRV and one outside the UK that did not, found no difference in vomiting nor VAP (1). In fact, the unit that did not measure GRV had a lower incidence of VAP, despite having longer ventilation times. Three adult studies of no GRV versus regular GRV measurement (13,14,15), two of which were randomized trials, found no different in VAP or aspiration. Increasing evidence in preterm neonates, (16,17) also suggests that

not measuring GRV, does not increase the risk of NEC (considered one of the major complications in this setting) and can reduce the time to achieve full enteral feeds. However, we do not have enough evidence in children to know that not measuring GRV is safe and whether there are specific patients in which we do need to use GRV to guide feeding. The two adult trials were predominantly in stable medical patients, with few surgical adults or those with shock.

Aspirate color was cited as important as the volume, and many unit guidelines referred to not returning aspirates that were bilious (green), fecal (brown) or bloody (red) in color. Change in aspirate color is viewed as a potential indicator of NEC in preterm neonates but this is also unsubstantiated by high quality evidence (18). As pediatric ICU clinicians work with term neonates and many pediatric intensivists have experience in neonatal intensive care, this is likely to influence their decision-making.

The first action in response to a GRV above the arbitrary threshold value were almost always to withhold enteral feeds for a period of time. Large international cohort studies have shown that interruptions to feeding (many reportedly caused by a 'large' GRV) are probably the biggest cause of failure to achieve energy targets in the critically ill (19, 20, 21). In critically ill adults, the most significant factor that affected the achievement of energy targets significantly was measuring GRV (22). Critically ill adults achieved 38% more of their estimated energy target if GRV was not measured. This, combined with evidence from three adult studies and one pediatric study showing that not measuring GRV did not impact of the incidence of VAP, and the fact that PICUs in 38% of French-speaking countries do not routinely measure GRV (5), are strong arguments for not measuring GRV routinely. However, changing pediatric intensive care culture where this practice is the norm, is more challenging, and having robust evidence from a randomized trial would be the first step to change culture.

We noted there was inconsistency between unit guidance and reported practice in the survey on occasions. This may reflect the reality of clinical practice, with evidence demonstrating that compliance with guidelines is often poor (22,23) in intensive care units.

There are some limitations of this study that warrant highlighting. Firstly as with any survey, responses may not reflect what actually happens in practice, however we were able to obtain a summary of what ought to happen through looking at unit guidelines. At times, the overall summary of reported practice differed to the summary of what guidelines suggest. However, this has given an insight into both reported practice (which is probably closer to actual practice) and written guidance. Despite these limitations, we had a high response rate across UK PICUs, and equal unit responses amongst cardiac and general PICUs, strengthening the generalisability of our findings.

CONCLUSIONS

The routine and frequent measurement of GRV is embedded into enteral feeding practice and guidelines in UK PICUs, yet little specific guidance is provided about the technique. This is despite a lack of evidence and questionable accuracy of this parameter. For most units, GRV is the main defining assessment of feed tolerance/intolerance, and the most commonly used threshold is a GRV ≥ 5ml/kg. This study has established current practice around GRV measurement in UK PICUs, which will enable us to develop a 'control' arm of a future trial of not routinely measuring GRV in critically ill children.

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REFERENCES

1. Tume LN, Bickerstaff A, Latten L et al. Routine gastric residual volume measurement and energy target achievement in the PICU: a comparison study. *Eur J Peds* 2017: Epub doi: 10.1007/s00431-017-3015-8
2. Tume LN, Valla FV. A review of feeding intolerance in critically ill children. *Eur J Peds* 2018; doi: 10.1007/s00431-018-3229-4
3. Tume LN, Latten L, Kenworthy L. Paediatric intensive care nurses' decision-making around gastric residual volume measurement. *Nurs in Crit Care* 2017; doi: 10.1111/nicc.12304
4. Tume LN, Balmaks R, da Cruz E et al. European Practices in enteral feeding in infants with congenital heart disease: an ESPNIC survey. *Ped Crit Care Med* 2017; doi: 10.1097/PCC.0000000000001412
5. Valla F, Gaillard-Le Roux B, Ford-Chessel C et al. NutriRea-Ped 2014: the Nursing Survey on Nutrition Practices in French-speaking Pediatric Intensive Care Units. *Ped Crit Care Med* 2015; doi: 10.1097/MPG.0000000000000930
6. Tume L, Carter B, Latten L. A UK and Irish survey of enteral nutrition practices in paediatric intensive care units *Br J Nutrition 2012;* doi:10.1017/S0007114512003042
7. Bartlett-Ellis R, Fuehne J. Examination of Accuracy in the Assessment of Gastric Residual Volume: a simulated, controlled study. *JPEN* 2015; 39(4): 434-440.
8. Lin H, van Citters G. Stopping enteral feeding for arbitrary gastric residual volume may not be physiologically sound: results of a computer simulation model. *JPEN* 1997; 21(5): 286-289.
9. Sangers H, de Jong P, Mulder SE et al. Outcomes of gastric residuals whilst feeding preterm infants. *J Neonatal Nurs* 2013; 19(6): 337-341.
10. Matinez E, Pereira L, Gura K et al. Gastric emptying in critically ill children. *JPEN* 2017; 41(7):1100-1109
11. Harris P, Taylor R, Thielke R et al.Research electronic data capture (REDCap) – A metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform*. 2009 Apr;42(2):377-81
12. Braun V, Clarke V. Using thematic analysis in psychology. *Qualitative Research in Psychology 2006; 3* 77-101.
13. Reignier J, Mercier E, Le Gouge A et al. Effect of not monitoring residual gastric volume on risk of ventilator-associated pneumonia in adults receiving mechanical ventilation and early enteral feeding. *JAMA* 2013; 309(3):
14. Ozen N, Tosun N, Yamanel L. et al. Evaluation of the effect on patient parameters of not monitoring gastric residual volume in intensive care patients on a mechanical ventilator receiving enteral nutrition: a randomized clinical trial *J Crit Care* 2016; 33: 137-144
15. Poulard F, Dimet J, Martin-Lefevre L et al. Impact of not measuring Residual Gastric Volume in Mechanically Ventilated Patients Receiving Early Enteral Feeding: a prospective before-after study *JPEN* 2010; 34(2): 125-130.
16. Torrazza RM, Parker LA, Li Y et al. The value of routine evaluation of gastric residuals in very low birth weight infants. *J Perinatol* 2015; 35: 57-60.

17. Riskin A, Cohen K, Kugelman A et al. The impact of routine gastric residuals' evaluation on time to full enteral feeds in preterm infants. *J Peds* 2017; 189:128-134. doi: 10.1016/j.jpeds.2017.05.054.
18. Li YL, Lin HC, Torrazza R et al. Gastric Residual Evaluation in Preterm Neonates: A useful Monitoring technique or a hindrance? *Pediatrics & Neonatology* 2014; 55: 335-340.
19. Leong A, Cartwright K, Guerra G et al. A Canadian survey of perceived barriers to initiation and continuation of enteral feeding in PICUs. *Ped Crit Care Med* 2013; 15: 2
20. Mehta N, Bechard L, Cahill N et al. Nutritional practices and their relationship to clinical outcomes in critically ill children – an international multicentre cohort study. *Crit Care Med* 2012; 40: 2204-2211
21. Mehta N, McAleer D, Hamilton S et al. Challenges to optimal enteral nutrition in a multidisciplinary pediatric intensive care unit. *JPEN* 2010; 34: 38-45.
22. Quenot JP, Plantefeve G, Baudel JL et al. Bedside adherence to clinical practice guidelines for enteral nutrition in critically ill patients receiving mechanical ventilation: a prospective, multicentre, observational study. *Crit Care* 2010; 14(2):R37
23. Abrahamson K, Fox R, Doebbeling B. Facilitators and Barriers to Clinical Practice Guideline use amongst nurses. *Am J Nurs* 2012; 112(17): 26-35.

Figure legends

Supplementary Appendix Survey Instrument

Table 1 Nutritional assessment routinely undertaken at PICU admission

Table 2 Summary of key GRV practices

Table 3 Detailed summary of UK PICU enteral feeding written guidelines

Table 1: Nutritional Assessment routinely undertaken at Pediatric Intensive Care Unit admission

Nutritional parameter assessed	N (%) (n=24)
Actual weight	20 (83%)
Estimated weight	14 (58%)
Height or length	13 (54%)
Z-score	4 (17%)
Centile chart	15 (62%)
Weight for age	4 (17%)
Nutritional assessment score	9 (37%)
STAMP	3/9 (33%)
PYMS	5/9 (56%)
BCH	1/9 (11%)

Respondents ticked all that applied

Abbreviations: STAMP: Screening Tool for the Assessment of Malnutrition in Paediatrics; PYMS Pediatric Yorkhill Malnutrition Score; BCH Birmingham Children's Hospital Score.

Table 2: Summary of Gastric Residual Volume Practices (Survey responses)

Practice	N (%) (n=24)
GRV is routinely measured	23 (96%)
There is an agreed feed intolerance definition	18 (75%)
The feed intolerance definition includes GRV	18/18 (100%)
Frequency of GRV measurement:	
Before every bolus feed	2 (8%)
4-hourly	18 (75%)
5-hourly / 6-hourly	3 (12%)
Only when child is vomiting	1 (4%)
Guidance is in place for GRV measurement technique	8 (33%)
The syringe size is specified	17 (70%)
Size of syringe*:	
20ml	5/17 (29%)
50ml / 60ml	10/17 (59%)
Size varies according to circumstance	2/17 (12%)
GRV is used to define maximum threshold	21 (88%)
Type of threshold:	
Maximum volume in ml/kg body weight	11/21 (52%)
Maximum volume percentage of administered feed	6/21 (29%)

Other	4/21 (19%)
GRV maximal threshold to define 'intolerance'*:	
5ml/kg	12 (50%)
Other ml/kg threshold (up to 10ml/kg/other)	2 (8%)
Gastric aspirate greater than 2 hrs / 4hrs / 6 hrs	4 (17%)
>50% of previous 4 hours of feed	3 (13%)
Reason for discarding GRV*:	
Abnormal color	17 (70%)

*Themes derived from free-text responses

Abbreviations: GRV Gastric Residual Volume

Table 3: Summary of Pediatric Intensive Care Unit Enteral Feeding Guidelines

PICU type	Default feeding method and route	GRV check frequency	Threshold for stopping feeds	Actions if threshold exceeded	Actions if still not tolerating feeds	Feeding defined by risk level: low vs high risk abdomen
1.Mixed general and cardiac PICU	Bolus gastric	3 hourly	5 ml/kg	Return GRV, stop feeds 3 h and re-check GRV	Consider continuous feeding, post-pyloric feeding, PN or prokinetics	No
2. Mixed general and cardiac PICU	Continuous gastric	4 hourly	5ml/kg	Return GRV, stop feeds 2 h and re-check GRV	Change to post-pyloric feeding	Yes
3. Mixed general and cardiac PICU	Bolus gastric	4 hourly	>4 hours of feed volume given	Replace GRV, continue feeding at same rate, re-check GRV at 4 hours	Stop feeds and review by doctor and dietician	No
4. Mixed general and cardiac PICU	Continuous gastric but also uses bolus	4 hourly	>4 hours of feed volume given or 200ml	Return GRV, stop feeds 2 h and re-check GRV, restart feed at 0.5-1ml/hr	Change to post-pyloric feeding	Yes
5. Mixed general and cardiac PICU	Bolus gastric	2-6 hourly to first determine the child's gastric emptying time and prior to every bolus feed	>50% of last bolus feed volume	Return GRV, stop feeds 2 h and re-check GRV	If GET delayed > 6 hours start post-pyloric feeding	No
6. Mixed general and cardiac PICU	Continuous gastric	4 hourly	5ml/kg or 200ml	Return GRV, stop feeds 2 h and re-check GRV	Withhold and discuss re post-pyloric feeding	No

7. Mixed general and cardiac PICU	Bolus gastric	Minimum 8 hourly but done before every 2 hour feed	5ml/kg or 300ml	Return GRV, stop feeds 2 h and re-check GRV	Change to continuous feeds, add oral prokinetic, or consider post pyloric feeding	No
8. Mixed general and cardiac PICU	Continuous gastric	4 hourly	5ml/kg	Return GRV, stop feeds 2 h and re-check GRV	If in first 48hour stop feeds, after 48 hour change to post-pyloric feeding	Yes
9. Cardiac ICU	Continuous gastric	4 hourly	5ml/kg	Return GRV, stop feeds 2 h and re-check GRV	Discuss with doctor and dietician	Yes
10. Cardiac ICU	Continuous gastric with somatic NIRS monitoring	4 hourly	>4 hours of feed volume given	Replace half GRV, stop feeds 2 h and re-check GRV	Consider post-pyloric feeding	Yes
11. General PICU	Continuous gastric	4 hourly	>4 hours of feed volume given	Return GRV, stop feeds 1 h and re-check GRV	No mention	No
12. General PICU	Continuous gastric	4 hourly	5ml/kg or 200ml	Return GRV and maintain rate of feed	Consider alternative feed, post-pyloric feeding or PN	No
13. General PICU	Continuous gastric but do use bolus	4 hourly	5ml/kg or 200ml	Return GRV, stop feeds 2 h and re-check GRV	Consider post-pyloric feeding	No
14. General PICU	Continuous gastric	4 hourly	5ml/kg or 200ml	Change to non-fibre feed and Return half GRV and continue on same rate for 4 h	Consider post-pyloric feeding and prokinetics	No

15. General PICU	Bolus gastric	4 hourly	>50% of the feed volume given in last 4 hours	Discard GRV and give the previous amount of feed again, re-check GRV	If still >50% change to continuous feeding, if still not tolerating IV prokinetic and by 72h start post-pyloric feeding	No
16. General PICU	Continuous gastric	4 hourly	5ml/kg	Return GRV, stop feeds 1 h and re-check GRV	Start prokinetics and post-pyloric feeding	No
17. General PICU	Continuous or bolus feeds	4 hourly	5ml/kg or 250ml	Return GRV, stop feeds 2 h and re-check GRV	Consider prokinetics, rule out constipation and consider post-pyloric feeding	Yes
18. General PICU	Continuous gastric	4 hourly	>50% of the feed given in last 4 hours	Notify medical/Dietician, stop feed or reduce rate and re-check GRV	Consider post-pyloric feeding if not tolerating by 24h	No
19. General PICU	Continuous gastric	6 hourly	>6 hours of feed given	Return GRV, stops feeds 1 h and re-check GRV	Does not specify	No

Abbreviations: GRV Gastric Residual Volume; GET Gastric Emptying Time; PN Parenteral Nutrition