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Aspiration and Evaluation of Gastric Residuals in the Neonatal Intensive Care Unit

State of the Science

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ABSTRACT

The routine aspiration of gastric residuals (GR) is considered standard care for critically ill infants in the neonatal intensive care unit (NICU). Unfortunately, scant information exists regarding the risks and benefits associated with this common procedure. This article provides the state of the science regarding what is known about the routine aspiration and evaluation of GRs in the NICU focusing on the following issues: (1) the use of GRs for verification of feeding tube placement, (2) GRs as an indicator of gastric contents, (3) GRs as an indicator of feeding intolerance or necrotizing enterocolitis, (4) the association between GR volume and ventilator-associated pneumonia, (5) whether GRs should be discarded or refed, (6) the definition of an abnormal GR, and (7) the potential risks associated with aspiration and evaluation of GRs. Recommendations for further research and practice guidelines are also provided.

Key Words: feeding, feeding tube, gastric residuals, neonatal intensive care unit, premature infant

In the neonatal intensive care unit (NICU), it is customary to routinely perform gastric residual (GR) aspiration and evaluation prior to every feeding in critically ill infants.[1] Aspiration and evaluation of GRs is thought to accomplish 3 tasks: (1) confirm correct orogastric/nasogastric (OG/NG) tube placement, (2) monitor whether the previous feeding remains in the stomach, and (3) prevent aspiration of gastric contents, which may contribute to ventilator-associated pneumonia (VAP).[1–3] It is unclear, however, whether routine aspiration and evaluation of GRs confers any clinical benefit and whether this practice should continue in the NICU. Specifically, there is insufficient evidence that aspiration and evaluation of GRs is a reliable indicator of OG/NG tube placement, assists in monitoring for feeding intolerance and necrotizing enterocolitis (NEC), or prevents aspiration of gastric contents.[4] In addition, there is lack of clarity regarding the volume and appearance of GRs deemed concerning whether GRs should be refed and the potential risks associated with the routine aspiration and evaluation of GRs. To determine potentially better practices for the NICU, this article summarizes available evidence regarding GR aspiration and evaluation in critically ill infants and offers recommendations for future research and clinical implications. Table 1 summarizes the current knowledge regarding GR aspiration and evaluation in the neonatal population.

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Table 1. **Current evidence regarding gastric residuals in neonates**

Questions Concerning GR Evaluation	Current Evidence
The use of GRs for verification of feeding tube placement	83% of nurses utilize this method An unreliable indicator of feeding tube placement 38% of attempts fail to obtain any aspirate Does not protect against placement in the `respiratory system
GRs as an indicator of gastric contents	An inaccurate estimate of gastric contents Varies with body position, feeding tube size, technique, feeding temperature, and viscosity
GRs as an indicator of feeding intolerance or NEC	No evidence it indicates feeding intolerance Prolongs time to achievement of full feeds Possible increased volume prior to NEC but extended time delay before diagnosis
The association between GR volume and VAP	Tracheal pepsin levels are higher when infants are fed No research on GR and VAP in neonates
Should GRs be discarded or refed	4% of nurses consistently refeed GRs Refeeding is supported in adults but no evidence in neonates
Definition of an abnormal GR	50% of the previous feeding in the most commonly utilized definition No formal consensus exists
Potential risks associated with aspiration and evaluation of GRs	The most common reason feeds are interrupted in adults Use of GR prolongs attainment of full feeds

Abbreviations: GR, gastric residual; NEC, necrotizing enterocolitis; VAP, ventilator-associated pneumonia.

USE OF GRs FOR VERIFICATION OF FEEDING TUBE PLACEMENT

An OG/NG tube correctly placed in the body of the stomach is necessary to avoid potentially serious complications including aspiration, apnea, bradycardia, desaturations, and trauma such as esophageal perforation.[5,6] While radiographic assessment is the criterion standard for verification of OG/NG tube placement, this technique is unfeasible in critically ill infants due to cost, time delay, radiation exposure, and the frequent need for OG/NG tube reinsertion. Therefore, assessment of OG/NG tube placement is routinely determined via clinically based methods.

Although the presence of an aspirated GR is an unreliable indicator of feeding tube placement, 83% of neonatal nurses continue to utilize this technique (L. A. Parker et al., unpublished data, 2014).[7,8] The absence of GR does not necessarily indicate malposition of the feeding tube and may be dependent upon multiple factors such as body position, gastric emptying time, previous feeding volume, and whether or not the feeding tube tip is positioned in the pool of gastric fluid. In fact, 38% of aspiration attempts in premature infants fail to obtain a GR.[9] Inadvertent placement of an OG/NG tube into the infant's respiratory system is the most serious complication of OG/NG tube placement. Unfortunately, a positive aspirate of what appears to be gastric contents does not ensure protection against this potentially life-threatening occurrence. Straw-colored aspirates can be obtained from the respiratory system, providing a false sense of security that the feeding tube is placed correctly within the stomach.[10]

GASTRIC RESIDUALS AS AN INDICATOR OF GASTRIC CONTENTS

The use of GR evaluation is based upon the assumption that the volume of aspirated GR is a valid and accurate measure of residual gastric content. While decisions regarding advancement or withholding of feedings are frequently made on the basis of the volume of aspirated GR, this volume may be significantly less than the actual residual gastric contents. Since errors in volume estimation increase as the volume of gastric contents decreases, errors may be particularly common in small premature infants.[11]

Gastric residual volume is also influenced by body position.[11,12] In a prospective study of 147 premature infants, Sangers et al found that larger GRs were aspirated from infants positioned left laterally or supine compared to a right lateral or prone position.[13] Similarly, Cohen et al[14] reported that GRs decreased in order of position: left lateral, supine, prone, and right lateral. Finally, Chen et al in a randomized time series with crossover study of 33 premature infants found a lower GR volume when infants were positioned prone.[15] However, in

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these studies, the volume of gastric contents remaining in the stomach was not verified making it unclear whether body position influenced gastric emptying or affected whether tube holes were more likely to be positioned in the pool of gastric fluid.

The size of the feeding tube can also influence GR volume, with larger-bore tubes aspirating up to 2 to 3 times the volume of smaller-bore tubes. This may be particularly important when caring for infants in the NICU where smaller-bore tubes are usual.[16] Positioning of the feeding tube holes within the pool of gastric fluid, aspiration technique, and feeding temperature and viscosity can all influence the volume of gastric contents aspirated.[16–19]

The majority of studies investigating the reliability of GR evaluation are limited by the use of in-vivo models where analysis of actual gastric content volume is impossible. To avoid this study limitation, Bartlett-Ellis and Fuchne used a simulated model of gastric aspiration to test known gastric content volumes. They found that aspirated GRs underestimated the actual gastric content volume by 19% and that this amount varied with feeding tube size, aspiration technique, and feeding viscosity.[20]

GASTRIC RESIDUALS AS AN INDICATOR OF FEEDING INTOLERANCE OR NEC

Premature infants frequently experience feeding intolerance due to gastrointestinal immaturity and decreased intestinal motility.[20,21] While the definition of feeding intolerance varies, the term is typically associated with the presence of emesis, visible bowel loops, increased abdominal girth, abdominal distension, and the presence of an abnormal GR.[22,23] Since the volume and appearance of GRs is one of the most commonly employed indicators of feeding intolerance, it is often used to determine advancement or withholding of enteral feedings.[1]

Necrotizing enterocolitis is a potentially fatal condition characterized by intestinal necrosis and inflammation affecting 7% to 11% of very-low-birth-weight (VLBW) infants[24–26] and is associated with a significant increase in morbidity and mortality.[27,28] The presence of abnormally large GRs has historically been thought to be an early indicator of NEC.[29,30]

The utilization of GRs as an indicator of feeding intolerance or an early sign of NEC is based on the following assumptions: (1) the volume of aspirated GR is an accurate measure of residual gastric contents; (2) the volume of GR provides information regarding gastric emptying; (3) an elevated GR volume indicates delayed gastric emptying and feeding intolerance; (4) a low GR volume indicates the stomach is emptying properly and the infant can tolerate feedings; and (5) elevated GRs are reflective of distal intestinal necrosis. Unfortunately, the validity of these assumptions has not been supported.

Feeding intolerance

Research in adults reveals a lack of evidence supporting the relationship between large GR volumes and feeding intolerance.[31] In a multicenter randomized clinical trial (RCT) of 449 critically ill adults, Reignier et al[32] found that subjects who underwent routine evaluation of GRs failed to meet their enteral nutritional goals. Similarly, there is a lack of evidence supporting the relationship between GR volume or appearance and feeding intolerance in the neonatal population. In the absence of other clinical signs, Mihatsch et al[1] found no correlation between light green GRs and either NEC or feeding intolerance in premature infants and suggested that light green GRs should not delay advancement of enteral feedings. In an RCT of 61 VLBW infants, Torrazza et al[33] found that undergoing routine aspiration and evaluation of GRs delayed attainment of full feedings (150 mL/kg/d) by 6 days and Shulman et al[34] found no correlation between enteral nutrition outcomes and GR volume.

Necrotizing enterocolitis

Cobb et al, in a case-control single-center study of VLBW infants (51 with NEC and 102 controls), investigated GR volumes during the 6 days prior to the diagnosis of NEC. Infants who were diagnosed with NEC had a maximum GR of 4.5 mL compared to 2 mL in the control group and the maximal residual, as a percentage of the previous feeding, was 40% in the NEC group and 14% in the control group. While differences were statistically significant, overlap in maximal residual volumes between groups potentially decreased the clinical relevancy of these findings. The authors suggested infants with a GR greater than 3.5 mL or 33% of the previous feeding were at higher risk of developing NEC.[29]

Bertino et al conducted a retrospective case-control single-center study of 17 VLBW infants with NEC and 17 control infants, comparing GRs from birth to the diagnosis of NEC. They found that infants diagnosed with NEC had significantly higher GRs. The maximum GR was 7.46 mL in infants diagnosed with NEC and 4 mL in control infants. Although this finding was statistically significant, there was a 17-day delay between obtainment of the maximum GR and the diagnosis of NEC. Infants with NEC were also more likely to experience hemorrhagic residuals, with a time delay of 19 days prior to diagnosis.[30]

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It is currently unclear whether the presence of large GRs is a reliable indicator of feeding intolerance or NEC and the definition of a "concerning" volume of GR is unknown. In addition, the timing of increases in GR volume prior to the diagnosis of NEC is unpredictable, preventing it from serving as a reliable red flag to warn of clinical deterioration.

Other less invasive assessment parameters may prove useful in monitoring for feeding intolerance and NEC such as emesis, visible bowel loops, increased abdominal girth, and abdominal distension and tenderness. These signs can provide important information for making clinical decisions and can be used as a guide to determine whether aspiration and evaluation of a GR is necessary. It may be reasonable to forego the routine evaluation of GRs and instead evaluate only in the presence of other gastrointestinal symptoms.[35] Li et al[36], in their feeding algorithm for preterm infants, suggest performing GR aspiration and evaluation only in the presence of other signs of feeding intolerance or NEC. In addition, they recommend considering further evaluation and treatment if the GR is greater than 50% of the previous feeding.[36] Algorithms such as this are essential to standardize the evaluation and treatment of GRs.

THE ASSOCIATION BETWEEN GASTRIC RESIDUAL VOLUMES AND VAP

Ventilator-associated pneumonia is defined as a nosocomial pneumonia that develops after more than 48 hours of ventilation.[37] Historically, large GR volumes have been thought to correlate with an increased risk of aspiration and VAP in both critically ill, ventilated children and adults.[3,38] This association was based upon the assumption that large GR volumes facilitated reflux of gastric contents into the esophagus, thereby increasing the risk of aspiration and VAP. However, the correlation between GR volume and VAP has not been well established and the lower limit of GR that may protect against aspiration is unknown.[39–41] A large RCT of 227 adults found no correlation between the routine evaluation of GRs and VAP in adults and it is likely that aspiration of oropharyngeal secretions poses a greater risk of VAP than aspiration of gastric contents.[31,42]

In critically ill infants in the NICU, the incidence of VAP ranges from 8.1% to 57.1%.[43] The use of uncuffed endotracheal tubes and the high prevalence of gastroesophageal reflux may place premature infants at a greater risk of aspiration and VAP.[44] While VAP is more common in infants who are enterally fed, little is known about the association between GR volume and VAP in this population.[43] Farhath et al found 92% of ventilated VLBW infants aspirated gastric contents, as evidenced by the presence of pepsin in tracheal secretions. Pepsin levels were highest when sampled during a feeding; however, the authors did not comment on the volume or presence of GRs.[45]

SHOULD GASTRIC RESIDUALS BE DISCARDED OR REFED?

Following aspiration, GRs are often discarded and decisions to discard or refeed GRs are generally based upon individual nurse's judgment, beliefs, and experiences as well as unit tradition.[46,47] In a small study of NICU nurses, only 4% consistently refed aspirated GRs.[46] If GRs are discarded, important elements including hydrochloric acid and pepsin may also be lost. Hydrochloric acid is essential in limiting the intestinal bacterial overgrowth of intestinal bacteria. If GRs are discarded, hydrochloric acid is lost, and the number of intestinal bacteria may increase, leading to intestinal inflammation and possibly increasing the risk of late onset sepsis and NEC.[48,49,50]

Juve-Udina et al randomized 125 adults to discard or refeed GRs. They found no increase in complications and improved gastric emptying in adults who were refed GRs.[47] In addition, a very small RCT with 35 adults found no difference in complication rates between refeeding and discarding GRs.[51] Unfortunately, no studies have been conducted regarding discarding or refeeding GRs in infants.

DEFINITION OF AN ABNORMAL GASTRIC RESIDUAL

Although important feeding decisions are made on the basis of GR volume, little consensus exists regarding the definition of an abnormally large GR or the point at which feedings should be decreased or withheld. Tremendous variation exists regarding the definition of an abnormal GR volume which may be based upon the total GR volume or more commonly upon a percentage of the previous feeding.[1,29] Previously published definitions have included 10% of the daily feeding volume,[52] greater than 30% of either the previous feeding[53] or more than 1 feeding,[54] and greater than 33% of the previous 1 to 2 feedings.[1,29] The most commonly cited parameter is a GR volume greater than 50% of a single feeding,[23,53] although 50% of 2 consecutive feedings[55] or 50% of 2 of the 3 previous feedings[56] have also been used. This lack of a clear definition of an abnormal GR results in significant variability in clinical practice.

Scant information also exists regarding how to adjust subsequent feedings in response to GR volume, for example, the length of time to withhold feedings, whether the entire volume of feeding should be withheld or whether the feeding should be decreased by

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a certain percentage. The lack of standardized feeding guidelines that address GR volume increases the probability that feeding decisions will be based upon individual clinician preference resulting in significant variation between and within institutions.

POTENTIAL RISKS ASSOCIATED WITH ASPIRATION AND EVALUATION OF GASTRIC RESIDUALS

Decisions regarding advancement or withholding of feedings are often based upon the volume of GR aspirated, so an earlier attainment of full enteral feedings may occur when GRs are not routinely evaluated.[57,58] The volume of feedings and the time necessary to attain full feedings are inversely related to the number of higher volume GRs.[1,59] Large GRs are the most common reason feedings are interrupted, with 96% of clinicians citing GRs as the main determinate in feeding decisions.[60,61]

The importance of adequate enteral nutrition in premature infants, including attainment of full enteral feedings, is well known and is necessary to facilitate optimal growth and development.[62] A delay in attainment of full enteral feedings is associated with significant complications, including adverse neurodevelopmental outcomes and prolonged need for parenteral nutrition (PN).[63,64] Extended use of PN is associated with PN-associated liver disease and the length of time infants receive PN increases the risk and severity of the PN-associated liver disease.[65] A central venous line is often required for administration of PN, resulting in an increased risk of late onset sepsis,[66,67] as well as more serious complications, including thromboembolic events and pericardial effusions.[68,69] Torrazza et al[33] reported that infants who did not undergo routine evaluation of GRs required a central venous line 6 fewer days than infants who did.

Aspiration of GRs may also damage the gastric mucosa due to the close contact of the feeding tube tip with the delicate gastric mucosa and the negative pressure required to withdraw the gastric contents. In addition, decisions to delay or discontinue enteral feedings due to aspiration of large GRs may alter secretion of essential gastrointestinal peptides. Since gastrointestinal peptides are important in the structural and functional development of the gastrointestinal system, alteration in secretion of these peptides may significantly affect feeding tolerance.[70]

DISCUSSION AND RECOMMENDATIONS

Routine aspiration and evaluation of GRs are standard procedure in most NICUs despite limited research concerning the risks and benefits. This article summarizes current knowledge regarding the most pressing issues surrounding the routine use of GR aspiration and evaluation. Discrepancies concerning the definition of an abnormal GR, a lack of consistency regarding the treatment of large GRs, and a lack of control for variables potentially altering the volume of gastric contents aspirated make interpretation of practice parameters and research difficult.[53,55] The presence of a small GR may provide a false sense of security, so it is necessary for clinicians caring for critically ill infants to be aware of the potential unreliability of GR evaluation.[71] Furthermore, the significant limitations associated with the use of GR aspiration and evaluation emphasizes the need for less invasive, innovative strategies to ensure infants in the NICU are provided with the highest level of care. Table 2 provides research opportunities and suggestions for practice parameters regarding aspiration and evaluation of GRs.

Since aspiration of a GR is an unreliable marker for correct OG/NG tube placement, other more reliable verification mechanisms are necessary. For example, the combination of more than 1 insertion method may increase the accuracy rate of feeding tube placement and charting the infant's insertion length in a visible location may help to verify correct feeding tube placement prior to the administration of a feeding.[72] Research specifically focused on neonates is needed to develop and validate insertion strategies such as previously published weight- and height-based formulas to improve the accuracy rate of feeding tube placement.[73,74]

Since GR aspiration is not a valid indicator of gastric content volume, its usefulness as a reliable assessment tool has been questioned and warrants further investigation.[18] If important clinical decisions are to be based on the volume of residual gastric contents, the utilization of a more accurate measurement strategy is necessary. An example of an alternative strategy is the use of abdominal ultrasound. Although, to date, this approach has not been used clinically, it has been shown to provide a valid and reliable measurement of gastric contents.[75] While abdominal ultrasound may not prove useful as a routine assessment tool, it may contribute valuable information for use when evaluating infants exhibiting other signs of feeding intolerance or NEC. If evaluation of GRs is utilized in feeding decisions, a more consistent definition of abnormal volume or appearance is necessary. Furthermore, guidelines defining when aspiration and evaluation of GRs is indicated need to be developed, along with the diagnostic and/or treatment strategies required when abnormally large GRs are obtained. Such guidelines are essential for the provision of evidence-based care.

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Table 2. **Research opportunities and practice suggestions regarding GR aspiration and evaluation**

Questions Concerning GR Aspiration and Evaluation	Research Opportunities	Practice Suggestions
Use of GRs for verification of feeding tube placement	Validation of methods previously reported in adults and children Innovative strategies to improve accuracy of insertion	Combination of more than 1 insertion method to improve accuracy rate Recording the infant's feeding tube insertion length at bedside for easy verification prior to feeding
GRs as an indicator of gastric content volume	The use of abdominal ultrasound to measure gastric content volume	GRs are not a reliable indicator of gastric content volume Careful assessment of other indicators of gastric content volume is necessary
GRs as an indicator of feeding intolerance or NEC	An RCT comparing feeding intolerance and NEC in infants who receive routine evaluation of GRs and those who don't	Use of alternative methods to assess for feeding intolerance and NEC including assessment of other clinical indicators Consider GR evaluation only when other clinical symptoms are present
The association between GR volume, aspiration, and VAP	An RCT comparing respiratory pepsin levels and the incidence of VAP in infants with and without routine evaluation of GRs	No current recommendations due to lack of evidence
Should GRs be discarded or refed	A RCT to determine the outcomes of infants who are refed GR and those who aren't	No current recommendations due to lack of evidence
Definition of an abnormal GR	Research regarding the risks of specific GR volumes	Guidelines are needed to define when to evaluate GRs and at what volume additional testing/intervention are required
Potential risks associated with aspiration and evaluation of GRs	RCT to compare indicators of gastrointestinal inflammation and bleeding and well as gastric enzyme and peptide levels between infants who undergo routine aspiration of GR and those who don't Research regarding the effect of routine evaluation of GRs on nursing workload and clinician stress	No current recommendations due to lack of evidence

Abbreviations: GR, gastric residual; NEC, necrotizing enterocolitis; RCT, randomized clinical trial; VAP, ventilator-associated pneumonia.

Although aspiration and evaluation of GRs occurs frequently in the NICU, the full range of potential associated risks is rarely considered. In addition to physiologic risks for infants, routine aspiration and evaluation of GRs also increases the bedside nurse's workload. The lack of specific guidance regarding when to report GR volumes to the physician or nurse practitioner may also potentially lead to increased work stress.

CONCLUSION

Scant information exists concerning the risks and benefits of performing routine aspiration and evaluation of GRs in the neonatal population. Although routine GR evaluation is considered a standard of care in most NICUs, its lack of reliability, as a measure of gastric contents and for verification of feeding tube placement, makes its clinical usefulness questionable. There is also insufficient evidence that its routine use can assist in the diagnosis of feeding intolerance or NEC or in preventing VAP. An adequately powered RCT is needed to specifically provide evidence as to whether routine aspiration and evaluation of GRs is a necessary clinical tool and if it causes inadvertent harm to the infant.

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