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Effects of not monitoring gastric residual volume in intensive care patients: A meta-analysis

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A B S T R A C T

Background: Monitoring gastric residual volume has been a common practice in intensive care patients receiving enteral feeding worldwide. Recent studies though, have challenged the reliability and necessity of this routine monitoring process. Several studies even reported improvements in the delivery of enteral feeding without monitoring gastric residual volume, while incurring no additional adverse events. However, the benefit of monitoring gastric residual volume remains controversial in intensive care patients.
Objective: The aim of this review is to identify the effects of not monitoring gastric residual volume in intensive care patients through a meta-analysis of the data pooled from published studies that meet our inclusion criteria.
Design: A systematic review
Data sources: An electronic search of Embase, Pubmed, and the Cochrane Library was completed up to April 2018. The data included basic population characteristics, related complications, mortality, duration of mechanical ventilation and intensive care unit length of stay.
Review methods: Eligibility and methodological quality of the studies were assessed by two researchers independently according to the Joanna Briggs Institute guidelines. The Review Manager Software was used to calculate the pooled risk ratio (RR), weighted mean difference, and the corresponding 95% confidential interval (95% CI). Sensitivity analyses were done by excluding each study. Publication bias analyses were conducted to avoid the exaggerated effect of the overall estimates.
Results: Five studies involving 998 patients were included in this meta-analysis. Compared with monitoring gastric residual volume, not monitoring gastric residual volume decreased the rate of feeding intolerance in critically ill patients (RR = 0.61, 95%CI 0.51–0.72), and did not result in an increment in the rate of mortality (RR = 0.97, 95%CI 0.73–1.29, P = 0.84) or the rate of ventilator-associated pneumonia (RR = 1.03, 95%CI 0.74–1.44, P = 0.85). There were also no differences in the duration of mechanical ventilation (MD = 0.09, 95%CI, −0.99 to 1.16, P = 0.88) or intensive care unit length of stay (MD=−0.18, 95%CI, −1.52 to 1.17, P = 0.79).
Conclusion: Except for an increased risk of vomiting, the absence of monitoring gastric residual volume was not inferior to routine gastric residual volume monitoring in terms of feeding intolerance development, mortality, and ventilator-associated pneumonia in intensive care patients. There is encouraging evidence that not measuring gastric residual volume does not induce additional harm to the patients. More multicenter, randomized clinical trials are required to verify these findings.

What is already known about the topic?

- Monitoring gastric residual volume has been a routine practice in the assessment of enteral nutritional tolerance and gastric emptying in the intensive care units.
- Whether gastric residual volume serves as a surrogate parameter indicating gastrointestinal tract dysfunctions in the intensive care units remains controversial.

What this paper adds

- Not monitoring gastric residual volume did not increase the incidence of feeding intolerance rates, ventilator-associated

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pneumonia rates, mortality rates, duration of mechanical ventilation or intensive care unit length of stay.
- A meta-analysis concerning the effect of not monitoring gastric residual volume on nutritional intake could not be performed due to different nutritional outcome measures.
- More large, randomized trials of high quality are required to demonstrate a definite answer to this crucial question.

1. Introduction

Malnutrition is prevalent in critically ill patients. It is estimated that the overall incidence of malnutrition in intensive care units could be above 50% (O'Meara et al., 2008). Hence, the provision of early enteral nutrition to patients in intensive care units is of great significance. This is crucial in maintaining structural and functional gut integrity, and supporting the humoral immune system, reducing mortality and increasing ventilator-free days (Alberda et al., 2009; Doig et al., 2009; Martindale et al., 2009). However, gastrointestinal tract dysfunctions are common in critically ill patients, reported between 7% and 46% of intensive care unit patients (Mentec et al., 2001; Rice et al., 2005; Ridley and Davies, 2011). Gastrointestinal tract dysfunctions include impaired gastric emptying and intestinal dysmotility, which may lead to regurgitation, raising the risk of aspiration and ventilator-associated pneumonia.

Monitoring gastric residual volume has been a routine practice for the assessment of enteral nutritional tolerance and gastric emptying in the intensive care units. The volume of the fluid obtained by aspirating the gastric content through an enteral tube using a syringe is called gastric residual volume (Edwards and Metheny, 2000). The amount of gastric residual volume could reflect the contents retained in the stomach, yet surprisingly, there is little scientific evidence to prove that gastric residual volume can be used to accurately determine feeding intolerance. Furthermore, a study carried out in a metrology laboratory showed that actual residual volume varied across tube size and viscosity, indicating that residual volume assessment does not precisely reflect the gastric content (Bartlett Ellis and Fuehne, 2015). The use of gastric residual volume as a surrogate parameter for gastrointestinal tract dysfunctions in the intensive care units is therefore a controversial topic (Elke et al., 2015; Emami Zeydi et al., 2016). The American Society for Parenteral and Enteral Nutrition recommended performing the measurement every 4 h with gastric residual volume amount more than 500 mL as an indicator for enteral nutrition interruption (McClave et al., 2009). Yet, the German Society for Nutritional Medicine pointed out that gastric residual volume measurement is not a reliable method, but the enteral nutrition delivery rate should be modified if vomiting occurs (Elke et al., 2015).

High gastric residual volume is a common reason for enteral nutritional interruptions (O'Meara et al., 2008; Yip et al., 2014). Feeding interruptions in critically ill patients may lead to an increased risk of infections with adverse outcomes (Heydari and Emami Zeydi, 2014). A prospective, observational study of adults admitted to surgical intensive care units showed that patients with enteral nutrition interruption were at a 3-fold increased risk of being underfed, having a 30% higher risk of prolonged intensive care unit stay and a 50% higher risk of prolonged hospital stay (Peev et al., 2015). Despite recent evidence, a paper-and-pencil survey of 2298 members of the American Association of Critical-Care Nurses revealed that more than 97% of the nurses reported performing routine monitoring gastric residual volume, and about 25% of the nurses reported interrupting feedings for the gastric residual volume of 150 mL or less (Metheny et al., 2012).

Several studies have been carried out to explore the effect of not monitoring gastric residual volume in intensive care units (Chen et al., 2015; Ozen et al., 2016; Poulard et al., 2010; Reignier et al., 2013; Tume et al., 2017). However, there is no meta-analysis in the literature concerning the risks and benefits associated with not monitoring gastric residual volume.

2. Objective

The objective of this review was to summarize and appraise the results of published research, to explore the effects of not monitoring gastric residual volume on vomiting, feeding intolerance, mortality, ventilator-associated pneumonia, duration of mechanical ventilation and intensive care unit length of stay for critically ill patients, in order to provide guidance for nurses in their daily management of enteral nutrition.

3. Methods

3.1. Literature search

An electronic search of Embase, PubMed, and the Cochrane Library(Cochrane Database of Systematic Reviews, Cochrane Central Register for Controlled Trials) was completed up to April 2018. MeSH terms combined with free terms were used to search for potentially relevant articles across databases, including "Enteral Nutrition", "Stomach", "Monitoring", "enteral feeding", "volume", and "residual gastric volume". These search strategies were presented in Appendix S1. The references of the identified studies were then screened for additional relevant studies.

3.2. Inclusion and exclusion criteria

The studies were screened using PICOS criteria as follows (Stang, 2010): (1) Participants (P): All of the patients admitted to the intensive care units; (2) Intervention (I) and Comparator (C): Not monitoring gastric residual volume was considered the intervention, and monitoring was considered the control; (3) Outcomes (O): Vomiting rate, feeding intolerance rate, ventilator-associated pneumonia rate, mortality rate, duration of mechanical ventilation, intensive care unit length of stay and nutritional intake were reviewed. Enteral feeding intolerance is defined as the occurrences of vomiting, diarrhea or high gastric residual volume values (Montejo et al., 2010). For nutritional intake measurements, cumulative calorie deficit and percentage of energy targets achieved were included in this review. The cumulative calorie deficit amount is calculated by subtracting the calorie amount provided daily to the patient from the calorie amount that the patient should have received daily(kcal) (McClave et al., 2009). Percentage of energy targets achieved is defined as the percentage of energy actually delivered vs. initially prescribed energy. The intensive care unit used predictive Schofield equations to set energy targets (Tume et al., 2017) and (4) Study Design (S): Considering the limited studies, we reviewed cohort studies and randomized controlled trials.

Studies were excluded if they met the following criteria: (1) Duplicate publications, (2) Review articles or case reports, (3) Contained insufficient information to extrapolate the data and (4) Full text was not available.

3.3. Selection of reviews

The lead author screened retrieved titles and abstracts to identify potentially relevant reviews. The full texts of these studies were assessed independently by researchers for eligibility and differences observed in the selection were resolved through a discussion.

3.4. Quality assessment and data abstraction

All included trials were appraised on the reporting of seven key methodological criteria: random sequence generation, allocation concealment, blinding of participants and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting and other bias (Higgins and Green, 2009). The quality assessment was conducted independently by two researchers after the final selection of the paper.

Data extraction was performed independently by two researchers. Basic information about the first author surname, publication year, country, study design, setting, patient population, sample size, patient age, gender and intervention details were extracted and analyzed. To compare the clinical outcomes of monitoring and non-monitoring groups, data on the vomiting rate, feeding intolerance rate, ventilator-associated pneumonia rate, mortality rate, duration of mechanical ventilation and intensive care unit length of stay were extracted. A formula adopted from previous studies was used to acquire the mean and standard deviation (Hozo et al., 2005). The mean is the average of all numbers. Standard deviation (SD) is a measure that is used to quantify the amount of variation or dispersion of a set of data values.

3.5. Statistical analysis

Review Manager Software(version 5.3, Cochrane Collaboration) was used to carry out all analyses. Combined data of the binary outcomes extracted from original studies were pooled to estimate the risk ratios (RRs) and corresponding 95% confidence intervals (CIs), while continuous outcomes were pooled to estimate overall weighted mean difference and corresponding 95% CIs. Heterogeneity was tentatively divided into absent and obvious heterogeneity. The I^2 test and Chi-square test were performed to assess heterogeneity (Bowden et al., 2011). $P < 0.1$ or $I^2 > 50\%$ meant significant heterogeneity (Higgins and Green, 2009; Higgins and Thompson, 2002). If the heterogeneity was significant, the random effects model was used for the analysis; otherwise, the fixed effect model was employed (Zintzaras and Ioannidis, 2005). Sensitivity analyses were done by excluding each study. Publication bias analyses were conducted to avoid the exaggerated effect of the overall estimates.

4. Results

4.1. Characteristics of the included studies

A total of 685 articles were initially obtained from Embase, Pubmed and the Cochrane Library. The study PRISMA flow diagram in Fig. 1 shows the literature selection process (Stovold et al., 2014). Finally, 5 studies involving 998 patients were included in this meta-analysis. The studies were conducted mainly in Europe and Asia, with two studies in France, one in Turkey, one in Asia, and one in UK and France. All of the included studies were implemented in patients receiving mechanical ventilation. Most of the patients had a medical diagnosis at admission to the intensive care units. The duration of treatment and follow-up ranged from 3 days to 90 days between studies. The gastric residual volume monitoring was performed with various frequency and volume thresholds, ranging from every 4 to every 8 h a day, with volume thresholds from 200 ml to 300 ml. The absence of monitoring gastric residual volume was noted in all studies, with minor variations. More relevant characteristics of the included studies are shown in Table 1. Fig. 2 summarized the risk of bias of these 5 eligible studies.

4.2. Review quality

The outcomes from the quality assessment of studies were inputted into Review Manager Software(version 5.3, Cochrane Collaboration) according to quality assessment judgment criteria, and results are shown on Fig. 2. The risks are assessed in response to low, high and unclear risks. Nearly half of the studies had a high risk in random sequence generation (40%), binding of outcome data (20%) and incomplete outcome data (20%). Since treatment was visible, only one observational pilot comparison study undertaken in two intensive care units had a low risk. The other four studies had a high risk in allocation concealment, and blinding of participants and personnel. Otherwise, all of the studies had a low risk in selective reporting and other bias.

4.3. Sensitivity analysis and publication bias

We performed a sensitivity analysis by omitting each study to ensure accuracy of the results. The results show a stable influence on the vomiting, feeding intolerance, ventilator-associated pneumonia and mortality. By excluding the study performed in the

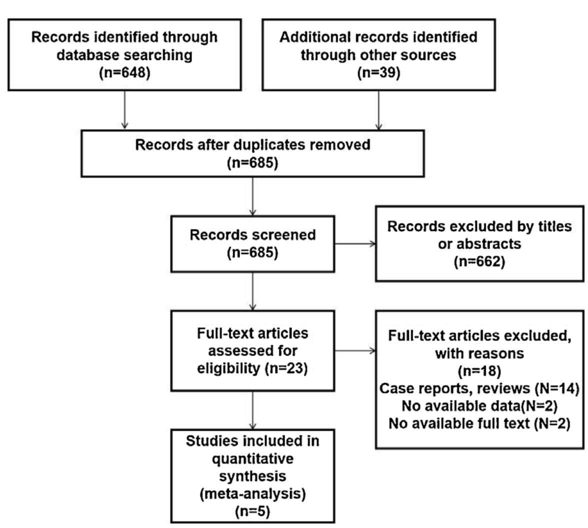

Fig. 1. Study selection process to identify eligible articles for inclusion in the review.

Table 1
Characteristics of the studies included in the review.

Author	Study Design	Nation	Setting	Patient Population	Sample size, no.	Mean age, years	Men, %	Control (monitoring GRV)	Intervention (not monitoring GRV)
Chen et al. (2015)	RCT	China	ICU	Stroke	206	61.3	54.8	GRV measured every 4 hours Guidance on adjusting infusion rate: GRV>200 mL.	No GRV No adjusting infusion rate
Ozen et al. (2016)	RCT	Turkey	ICU	Respiratory, Cardiac arrest(>80%)	51	66.5	62.7	GRV measured every 8 hours Guidance on stopping EN:GRV > 250 ml or intolerance signs and symptoms	No GRV Guidance on stopping EN:vomiting, regurgitation, diarrhea/constipation or abdominal distention
Poulard et al., (2010)	Before-After Study	France	ICU	Acute respiratory failure, Acute central nervous failure,Sepsis (>70%)	205	62.5	67.8	GRV measured every 6 hours Guidance on decreasing delivery rate:GRV > 250 ml or vomiting	No GRV Guidance on decreasing delivery rate: vomiting
Reignier et al. (2013)	RCT	French	ICU	Respiratory, Cancer, Immune deficiency (>30%)	449	61.5	70.2	GRV measured every 6 hours Guidance on using gastric prokinetic drug and decreasing nutrition flow rate: GRV > 250 ml or vomiting	No GRV Guidance on using gastric prokinetic drug and decreasing nutrition flow rate:vomiting
Tume et al. (2017)	Observational pilot comparison study	UK and France	PICU	Respiratory failure (>50%)	87	7.5	59.8	GRV measured every 4–5 hours, Guidance on stopping EN:Vomiting, abdominal distension, pain;If lactate> 2 mmol/l, large GRV > 5 ml/kg or 300 ml	No GRV Guidance on stopping EN:Vomiting, abdominal distension, pain

*GRV: gastric residual volume; EN: enteral nutrition; ICU: intensive care unit; PICU: pediatric intensive care unit; RCT: randomized controlled trial.

pediatric intensive care unit, a stable influence on the duration of mechanical ventilation and intensive care unit length of stay was revealed. There was no obvious publication bias on visual examination of the funnel plots (Fig. 3). However, due to limitations of the Review Manager Software, this visual assessment of publication bias lacked reliability.

4.4. Effect of not monitoring gastric residual volume on vomiting and feeding intolerance

Five studies were included in the primary analysis of vomiting. After aggregating the data, monitoring gastric residual volume was associated with a significant increase in the rate of vomiting (RR = 1.43, 95%CI 1.15–1.77, P = 0.001, Fig. 4). Three studies were included in the primary analysis of enteral feeding intolerance. Not monitoring gastric residual volume was associated with a significant decrease in the rate of feeding intolerance in critically ill patients(RR = 0.61, 95%CI 0.51–0.72, P < 0.001, Fig. 4).

4.5. Effect of not monitoring gastric residual volume on ventilator-associated pneumonia

Three trials reported ventilator-associated pneumonia rate as an outcome. Compared with the monitoring group, patients in the non-monitoring group did not exhibit a significant difference in the likelihood to develop ventilator-associated pneumonia (RR = 1.03, 95%CI 0.74–1.44, P = 0.85). Fig. 5 shows a forest plot comparing the control groups and intervention groups.

4.6. Effect of not monitoring gastric residual volume on mortality

Meta-analysis of 705 patients from three studies in intensive care units demonstrated no significant increase in mortality between monitoring and non-monitoring groups (RR = 0.97, 95%CI 0.73–1.29, P = 0.84). However, moderate heterogeneity was present between these trials ($p_{heterogeneity} = 0.13$; $I^2 = 51\%$). See Fig. 6 for full details.

4.7. Effect of not monitoring gastric residual volume on the duration of mechanical ventilation and intensive care unit length of stay

A meta-analysis of four studies failed to find any impact on the duration of mechanical ventilation(Mean Difference(MD) = 1.80, 95%CI, −2.45 to 6.05, P = 0.41) and intensive care unit length of stay (MD = 1.32, 95%CI, −3.43 to 6.07, P = 0.59). Notable heterogeneity was present between these trials ($p_{heterogeneity}<0.001$, $I^2 = 90\%$; $p_{heterogeneity}<0.001$, $I^2 = 89\%$). Considering the different settings in these studies, we excluded the study performed in the pediatric intensive care unit. In the subgroup analysis, there was no difference between monitoring and non-monitoring groups in the duration of mechanical ventilation and intensive care unit length of stay (MD = 0.09, 95%CI, −0.99 to 1.16, P = 0.88; MD=-0.18, 95%CI, −1.52 to 1.17, P = 0.79, Fig. 7).

4.8. Effect of not monitoring gastric residual volume on nutritional intake

Four studies investigated the effect of not monitoring gastric residual volume on nutritional intake (Ozen et al., 2016; Poulard et al., 2010; Tume et al., 2017). One study reported that the number of calories provided was significantly higher in the non-monitoring group than the monitoring group as reflected by a lower cumulative calorie deficit(P < 0.05) (Ozen et al., 2016). Another study demonstrated that the volume of enteral feeding per day was significantly higher in the non-monitoring group than that in the monitoring group (P = 0.002) (Poulard et al., 2010). A large randomized controlled trial also found a lower cumulative calorie deficit in patients without gastric residual volume monitoring (Reignier et al., 2013). The study conducted in a pediatric intensive care unit revealed no correlation between the percentage of energy targets achieved and the presence of gastric residual volume monitoring (Tume et al., 2017). However, a meta-analysis could not be performed due to diverse outcome measures.

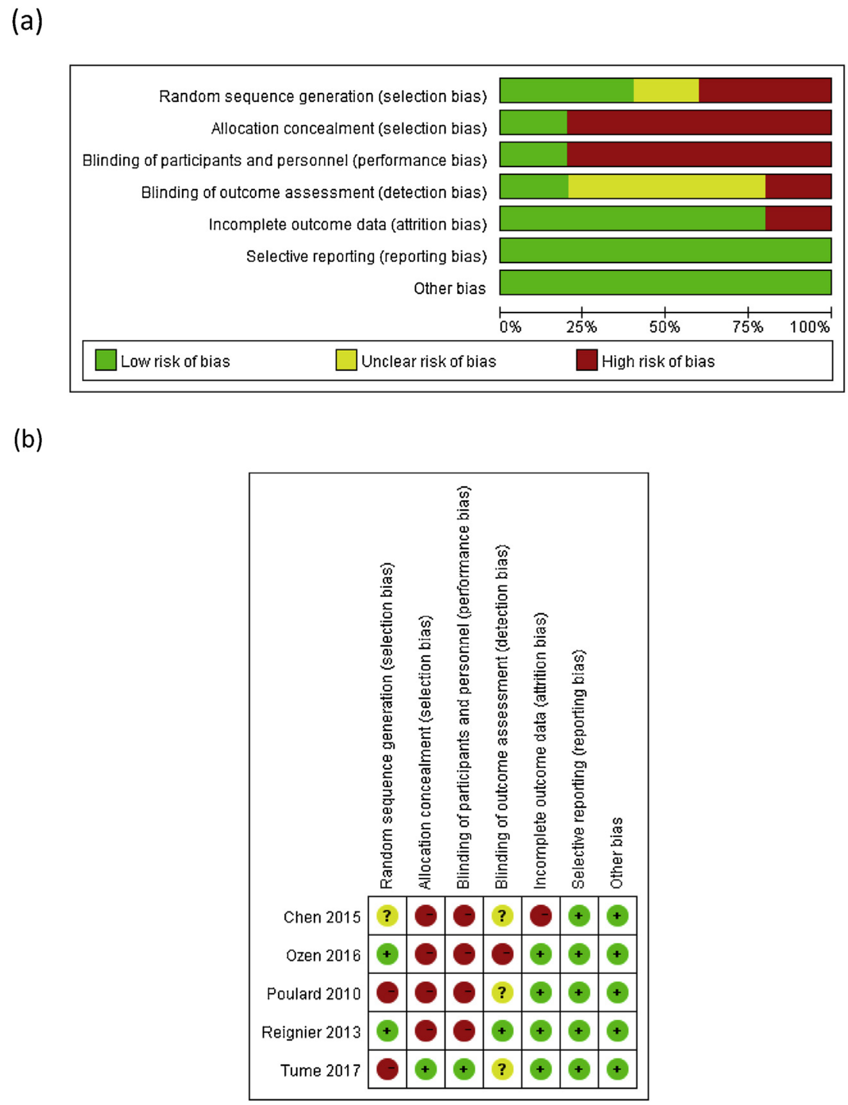

Fig. 2. Risk of bias graph (a) and summary (b): review author's judgements about each domain presented as percentages across included studies.

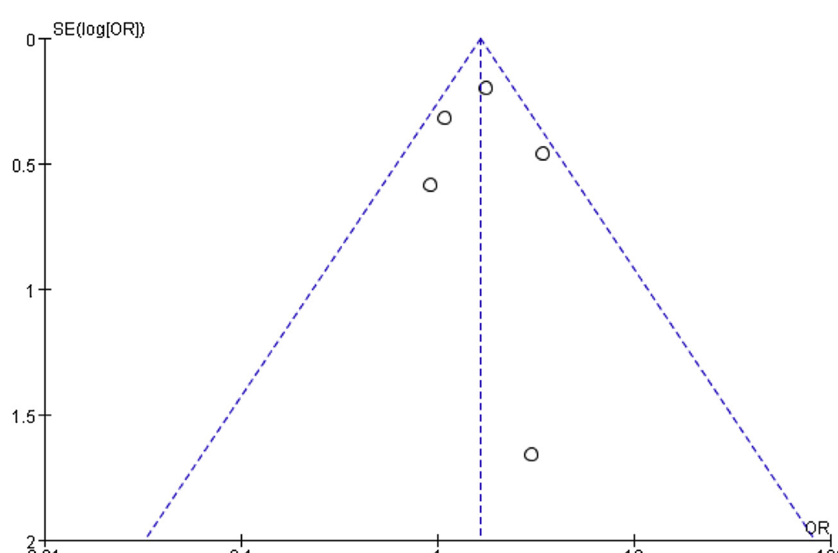

Fig. 3. Funnel plot of publication bias of all included studies with vomiting as an outcome.

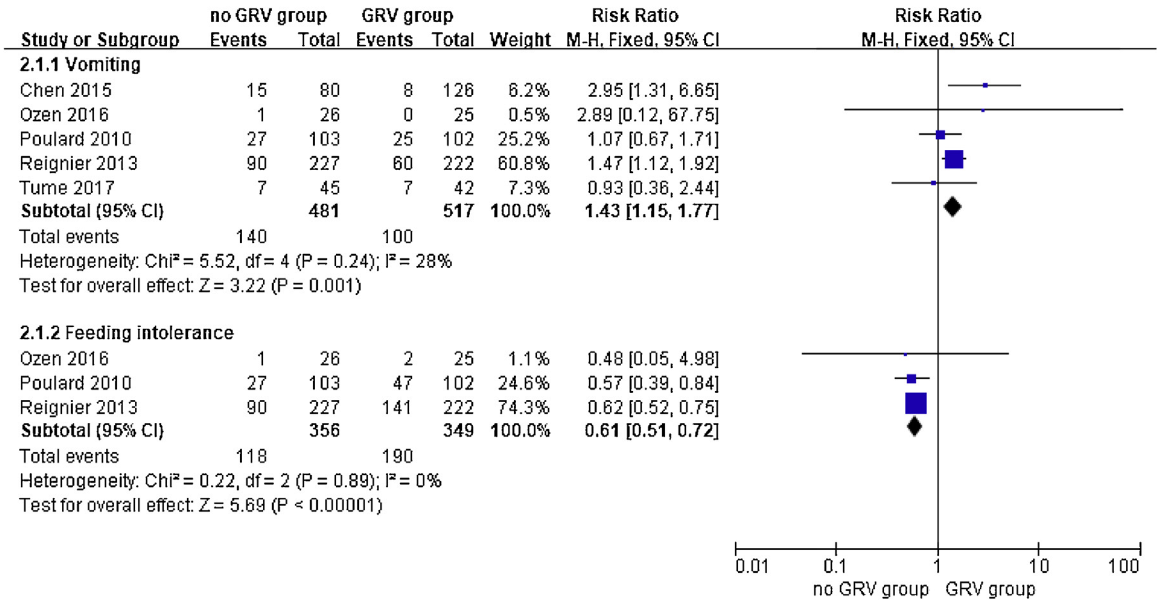

Fig. 4. Effect of not monitoring gastric residual volume on vomiting and feeding intolerance.

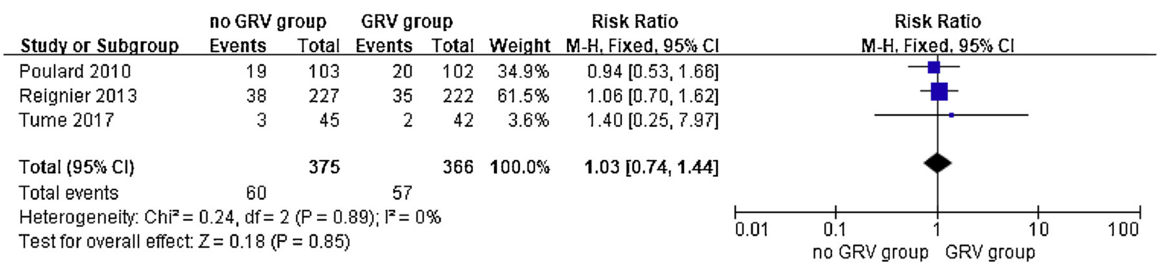

Fig. 5. Effect of not monitoring gastric residual volume on ventilator-associated pneumonia.

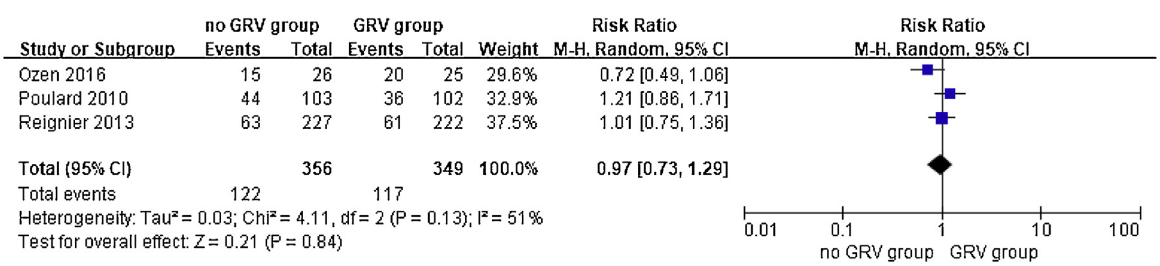

Fig. 6. Effect of not monitoring gastric residual volume on mortality.

5. Discussion

To our knowledge, no meta-analysis has been carried out about the risks and benefits associated with not monitoring gastric residual volume in intensive care patients. Except for an increased risk of vomiting, the results of this review show that the absence of monitoring gastric residual volume is not inferior to monitoring gastric residual volume in terms of feeding intolerance rates, ventilator-associated pneumonia rates, mortality rates, duration of mechanical ventilation and intensive care unit length of stay. To date, there is a paucity of evidence in literature for the practice of monitoring gastric residual volume, especially since it has been shown to be inaccurate due to a multitude of factors including tube position in the stomach, diameter of nasogastric tube, syringe size, level of aspiration in the stomach, and experience of the evaluator (McClave et al., 2005; McClave and Snider, 2002).

We found that monitoring gastric residual volume decreased the rate of feeding intolerance in critically ill patients. Similar results were obtained in earlier studies (Montejo et al., 2010). In general, feeding intolerance is among the top factors contributing to interruption of enteral nutrition in intensive care patients (McClave et al., 2009). Therefore, monitoring gastric residual volume may increase the rate of respiratory infection complications and 30-day mortality (Mogensen et al., 2015; Rubinson et al., 2004; Villet et al., 2005). Not monitoring gastric residual volume was associated with a significant increase in the rate of vomiting in our review. However, definition of vomiting relied on data reported by nurses, who may have responded to the absence of monitoring gastric residual volume by over reporting vomiting (Reignier et al.,

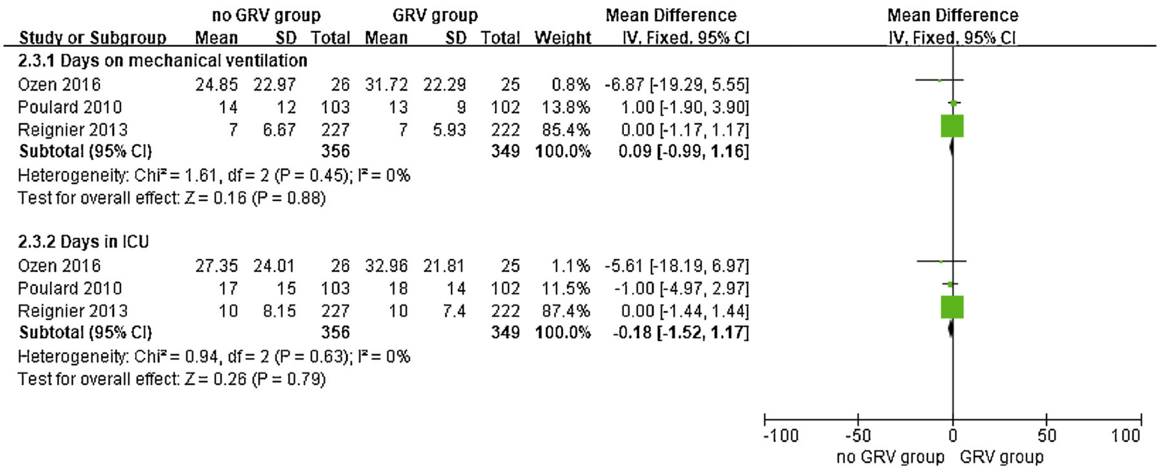

Fig. 7. Effect of not monitoring gastric residual volume on Days on MV and Days in intensive care unit.

2013). Besides, prokinetic drug use was lower in the non-monitoring group (Reignier et al., 2013). Despite a higher vomiting rate without monitoring gastric residual volume, the rate of feeding intolerance was decreased in our review. Several reasons may explain these results: First, the gastric residual volume thresholds for individual patients should differ enormously due to individualized enteral nutritional tolerance, and an elevated gastric residual volume may simply be a physiologic occurrence (Williams et al., 2014). 80% of critically ill patients who showed an elevated gastric residual volume never experienced a second episode despite continued feeding (Spain et al., 1999). Besides, gastric residual volumes are theoretically plateau between 232 and 464 mL/hr within 36 h of initiating feeds (Lin and Van Citters, 1997). The arbitrarily low threshold may not be clinically appropriate or physiologically sound (McClave et al., 2005). Thresholds ranged from 200 ml to 300 ml in our review. Therefore, feeding intolerance could be overestimated through gastric residual volume measurement. Second, the definition of feeding intolerance is the presence of vomiting, abdominal distention, diarrhea, and high gastric residual volume values (Montejo et al., 2010). Due to limited studies, a meta-analysis concerning diarrhea or abdominal distention was not performed.

The lack of significant increase in ventilator-associated pneumonia in non-monitoring gastric residual volume group is consistent with various previous clinical trials. High gastric residual volume values are not independently associated with adverse outcomes, as no evidence has been provided that decreasing the cutoff promote decreasing rates of aspiration or ventilator-associated pneumonia (Lin and Van Citters, 1997). Routine practice of monitoring gastric residual volume was based on the theory that gastric over distension may lead to regurgitation and aspiration, contributing to ventilator-associated pneumonia. However, this meta-analysis did not provide any evidence and other clinical factors may have a greater impact on the development of ventilator-associated pneumonia. In a recent microbiological and radiographic study, commensal oropharyngeal flora appeared to be a potential cause of ventilator-associated pneumonia, although whether the stomach is a pathogen reservoir is still controversial (Scholte et al., 2015). Other routine practices such as head of bed elevation (30°–45°), daily oral care, endotracheal tube cuff pressure monitoring and daily assessment of readiness to extubate play a more important role in decreasing ventilator-associated pneumonia rates (Okgun Alcan et al., 2016). On average, a nurse spends 5.25 min for a gastric residual volume measurement, which results in both loss of time and increased cost (Ozen et al., 2016). If gastric residual volume monitoring is removed from the daily routine, nurses would devote more energy to other more impactful interventions to decrease the risk of ventilator-associated pneumonia (Rello et al., 2013).

A meta-analysis concerning nutritional intake was not performed due to the use of diverse outcome measures. However, similar results could be found in previous studies. An observational, multicenter study in 19 intensive care units showed a 38% increase in the risk of having a low ratio of delivered/prescribed calories resulting from measuring gastric residual volume (Quenot et al., 2010). Further, larger trials with standardized nutritional outcomes are required to explore the relationship between not monitoring gastric residual volume and nutritional intake.

6. Limitations

Some limitations of this review need to be considered. First of all, we included both cohort studies and randomized controlled trials, limiting our ability to determine a causal relationship. However, a sensitivity analysis was conducted to assess the publication bias, and a stable influence was revealed. Lack of blinding is also apparent in most of the studies, as neither the nursing staff nor the patients could be blinded to monitoring gastric residual volume. Subtle differences in techniques used for treatments and follow-ups among the studies also made it difficult for the measurements to be entirely uniform. A meta-analysis on nutritional intake was not performed due to different outcome measures used. Moreover, most of the patients in our review had a medical diagnosis at admission to the intensive care units, which could limit the generalization of our results. A previous review revealed that monitoring gastric residual volume appears unnecessary in guiding nutrition for mechanically ventilated patients with a medical diagnosis (Kuppinger et al., 2013). More large, randomized trials are required to provide a definite answer to this crucial question.

7. Conclusions

Overall, we found that not monitoring gastric residual volume did not increase the incidence of feeding intolerance rates, ventilator-associated pneumonia rates or mortality rates. There were also no differences in the duration of mechanical ventilation or intensive care unit length of stay. However, not monitoring gastric residual volume was associated with a significant increase in the rate of vomiting in this review. Although monitoring gastric residual volume seems to bring unnecessary interruptions for enteral nutrition with subsequent inadequate feeding, we cannot draw conclusions regarding this issue due to diverse nutritional outcome measures of these trials. Therefore, the routine practice of monitoring gastric residual volume needs to be questioned, and more multicenter, randomized clinical trials of high quality are required to verify these findings in the future.

Conflicts of interest

None.

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