Introduction

Rapid-sequence induction (RSI) is a commonly used anesthetic technique for patients considered at risk for regurgitation and pulmonary aspiration. This technique consists of preoxygenation, cricoid pressure, and the avoidance of positive-pressure ventilation until the airway has been secured with an endotracheal tube. Patients at risk for aspiration include those with “full stomachs” and patients with a history of gastrointestinal surgery, hiatal hernia, gastroesophageal reflux disease, esophageal motility disorders, hyperchlorhydria, peptic ulcer, obesity, or diabetes mellitus.1

Although RSI is well established in anesthetic practice, it is not without possible risk to the patient. The most alarming risk is the potential inability to secure an airway or to ventilate a patient who is unconscious and apneic. The decision to use RSI needs to be based on a thorough assessment of a patient’s potential risk of aspiration and the potential risks associated with RSI. Potential risks of RSI include inability to ventilate leading to hypoxia and hypercarbia, alteration in heart rate and blood pressure, and trauma to the airway. These risks may not be warranted or appropriate for a patient at minimal risk of regurgitation and aspiration. For these cases, a modification of the standard RSI technique consisting of preoxygenation, cricoid pressure, and gentle positive-pressure ventilation before tracheal intubation may be more appropriate. The purpose of this study was to determine whether any such modification of RSI technique is used currently in clinical practice.

The purpose of this study was to identify the use of rapid-sequence induction (RSI) and its hybrids. For the study, 67 Certified Registered Nurse Anesthetists at 1 hospital completed a survey describing their experience using a modified technique for patients with a moderately increased risk of regurgitation and aspiration. Patient selection criteria and the use of aspiration prophylaxis, preoxygenation, cricoid pressure, and positive-pressure ventilation were evaluated. In contrast with routine induction and standard RSI techniques, the modified RSI technique consisted of aspiration prophylaxis, preoxygenation, application of cricoid pressure, and positive-pressure ventilation. The survey revealed that a modification of standard RSI is used commonly in clinical practice. These modified RSI techniques are not standardized, as variation was noted in the delivery of positive pressure ventilation. Further study is necessary to identify widespread use of modified RSI techniques and to clarify the risks and benefits of modified RSI.

Key words: Modified rapid-sequence induction, preoxygenation, cricoid pressure, positive-pressure ventilation.

The primary objective of RSI is to minimize the time between patient loss of consciousness and tracheal intubation. RSI is a standard technique consisting of preoxygenation and cricoid pressure.2 Positive-pressure ventilation generally is avoided until the airway is secured with an endotracheal tube, unless attempts at intubation are unsuccessful or desaturation occurs. Considerable variation, however, exists among anesthesia providers in the use of this technique. Variability exists in the duration of preoxygenation; the selection, dosage, and timing of administration of the induction agent and muscle relaxant; the use of adjunct medications; the application of cricoid pressure; and the management of a failed intubation.2

Preoxygenation is a standard component of RSI.2 According to basic anesthetic texts, preoxygenation on high fresh gas flows of 100% oxygen via face mask with a good mask fit for 3 to 5 minutes is recommended. Alternatively, a series of 4 vital capacity breaths of 100% oxygen may be used in an emergency.3,4

Sodium thiopental is selected most frequently as the induction agent in RSI.2 Other agents used include ketamine,5 etomidate,6 and propofol.7 Succinylcholine has long been considered the “gold standard” muscle relaxant for RSI, but adverse effects such as arrhythmias, hyperkalemia, and fasciculations may preclude its safe use in certain situations such as burn injury or spinal cord injury. Other muscle relaxants that can be considered include vecuronium8-10 and rocuronium.9,10-12 Nondepolarizing muscle relaxants, however, have a significantly longer duration of action than suc-
cincholamine and could prove disastrous if a patient could not be adequately ventilated or intubated. Non-depolarizing muscle relaxants also may be undesirable for surgical procedures of short duration.

The timing of administration of the induction agent in relation to the muscle relaxant in RSI also seems to be variable. In 1 study of 210 anesthetists, the muscle relaxant was administered immediately after the induction agent by 46.5% of anesthetists, after loss of lid reflex by 38% of anesthetists, and after loss of verbal contact by 15% of anesthetists. Other descriptions of RSI include administration of muscle relaxant 5 seconds after administration of the induction agent or even before administration of the induction agent. In any event, the rapid administration of a barbiturate with an alkaline pH and a muscle relaxant with an acidic pH can result in immediate and substantial precipitation and occlusion of the intravenous line. The loss of intravenous access after a patient loses consciousness and protective airway reflexes might prove disastrous.

Another key component of RSI is the application of cricoid pressure. Cricoid pressure consists of compression and occlusion of the esophagus in an attempt to minimize the risk of regurgitation. Cricoid pressure has been demonstrated to prevent air entry into the stomach as long as a patent airway is maintained. Excessive force applied to the cricoid cartilage can obstruct the airway and interfere with successful tracheal intubation. Possible complications of cricoid pressure include difficult tracheal intubation, airway obstruction, pulmonary aspiration, and esophageal rupture. Other unusual but reported complications include bilateral subconjunctival hemorrhage from a patient bucking against cricoid pressure and cricoid cartilage fracture.

Positive-pressure ventilation generally is avoided to prevent aspiration and gaseous distention of the stomach in RSI. This, however, precludes the ability to "test the airway" and verify that a patient can be ventilated by mask before the administration of a muscle relaxant. This also mandates a period of apnea that may not be well tolerated by patients with compromised respiratory status or increased baseline oxygen requirements.

The use of a modified RSI technique would allow for a patient to be gently ventilated by mask before the insertion of an endotracheal tube. Positive-pressure ventilation via a face mask could be provided before administration of a muscle relaxant to test the airway in patients with an airway assessed as marginal. Alternatively, positive-pressure ventilation via a face mask could be provided before and after administration of a muscle relaxant for patients unable to tolerate the brief period of apnea associated with RSI. An extensive review of the literature, however, has revealed no descriptions of a modified RSI technique for these patients.

Materials and methods
This descriptive study consisted of a survey of Certified Registered Nurse Anesthetists (CRNAs) employed at a large tertiary care hospital located in the southeastern United States. The anesthetists were asked to complete a survey describing their experience performing both RSI and modifications of RSI in their clinical practice. CRNAs who reported having used a modified RSI technique were asked additional questions to determine how patients were selected and whether preoxygenation, cricoid pressure, and positive-pressure ventilation were used. One of the investigators (S.S.) developed the data collection tool for the sole purpose of this study.

The survey (Figure 1) included 4 basic questions on the anesthetist's experience, practice setting, and use of RSI and modified RSI techniques. CRNAs who reported using a modified RSI technique in clinical practice were asked 5 additional questions regarding patient selection, provision of prophylaxis for aspiration pneumonia, preoxygenation, cricoid pressure, and positive-pressure ventilation.

Institutional review board approval was obtained before the distribution of surveys to all employed CRNAs in the inpatient and outpatient operating rooms. Responses were compiled and analyzed to identify the frequency of clinical use of RSI and modified RSI techniques, CRNA experience, and clinical practice setting. For CRNAs who reported using a modified RSI technique in clinical practice, further review of the data identified patient selection considerations and the anesthetist's definition of the modified RSI technique.

Results
Of 84 surveys distributed, 67 were returned for an overall response rate of 80%; 31 CRNAs (46%) had more than 10 years of clinical experience, 21 (31%) had 5 to 10 years of experience, and 15 (22%) had fewer than 5 years of experience. Of the 65 respondents who answered question 2 (type of practice setting), 51 (78%) were employed primarily in the inpatient operating room, while 14 (22%) were employed primarily in the outpatient department (Figures 2 and 3).

Nearly all respondents reported using both RSI and modified RSI techniques in their clinical practice (Figure 4). The reported use of a standard RSI tech-
**Modified rapid-sequence induction (RSI) techniques**

A Survey of Current Clinical Practice

RSI is a commonly used procedure in patients with ‘full stomachs’ to minimize the risk of regurgitation and aspiration. Standard components of RSI are preoxygenation, cricoid pressure and the avoidance of positive pressure ventilation via face mask until an endotracheal tube is placed. In some circumstances, a modification of this rapid-sequence technique may be warranted. The purpose of this questionnaire is to identify the clinical definition of modified RSI.

Please select the response that most closely reflects your current clinical practice.

1. Years anesthesia experience
   - < 5 years
   - 5-10 years
   - > 10 years

2. Type of practice setting
   - Inpatient operating room
   - Outpatient operating room

3. In my clinical practice, I currently use RAPID-SEQUENCE INDUCTION (RSI)
   - Never
   - Rarely
   - Occasionally
   - Often
   - Always

4. In my clinical practice, I currently use MODIFIED RSI
   - Never
   - Rarely
   - Occasionally
   - Often
   - Always

If you have NEVER used a modified RSI technique in your clinical practice, THANK YOU for your participation. If you have used a MODIFIED RSI technique, please answer the following questions.

5. Patients that I have utilized a MODIFIED RSI technique upon include: (check all that apply)
   - Moderately obese patients
   - Morbidly obese patients
   - Diabetic patients with no clinical symptoms of reflux disease
   - Patients with a history of prior esophageal surgery
   - Patients with a history of GERD but with no recent symptoms
   - Other. Please explain: ____________________________________________________

6. Based on your definition of modified RSI, is aspiration prophylaxis appropriate?
   - No
   - Yes
   If Yes, your usual management is: (check all that apply)
     - Premedication with sodium citrate
     - Premedication with metoclopramide
     - Premedication with H2 antagonist
     - Other: _____________________________________________________________ (please specify)

7. Based on your definition of Modified RSI, is preoxygenation required prior to induction?
   - No
   - Yes
   If Yes, for how long? (select the best answer)
     - PreO2 on 100% × > 5 min
     - PreO2 on 100% × 3-5 min
     - PreO2 on 100% × < 3 min
     - PreO2 on 100% × 4 vital capacity breaths

8. Based on your definition of modified RSI, is the application of cricoid pressure necessary?
   - No
   - Yes
   If yes, when is it applied? (select the best answer)
     - Prior to induction agent
     - At the same time as induction agent
     - After loss of lid reflex
     - After loss of verbal contact

9. Based on your definition of modified RSI, is an attempt to ventilate via face mask appropriate?
   - No
   - Yes
   If yes, when do you attempt to ventilate? (select the best answer)
     - PRIOR to administration of a muscle relaxant
     - FOLLOWING administration of muscle relaxant
     - BOTH before and after administration of muscle relaxant

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*GERD indicates gastroesophageal reflux disease; PreO2 indicates preoxygenation.*
nique was described as “often” by 45 (67%) and “occasional” by 20 (30%). Only 2 respondents (3%) reported “never” or “rarely” having used a standard RSI technique. No CRNA reported “always” using a standard RSI technique.

Of the respondents, 65 (97%) reported they have used a modified RSI technique in their clinical practice. The use of this technique was described as “occasional” by 42 (63%), “often” by 19 (28%), and “always” by 1 (1%). Only 3 (4%) reported “rarely” using a modified RSI technique.

The 65 CRNAs who reported using a modified RSI technique were asked to answer 5 additional questions on the survey. Five patient scenarios were described, and the anesthetists were asked to identify those in which they had used a modified RSI technique for the induction of general anesthesia. A total of 57 respondents (88%) reported they had used a modified RSI technique for patients with moderate obesity, while 23 (35%) reported its use for patients with morbid obesity. In addition, 43 respondents (66%) reported they had used modified RSI for patients with diabetes who had no current signs and symptoms of reflux disease. For patients with a history of esophageal surgery, 18 (28%) responded they had used a modified RSI technique. For patients with a history of gastroesophageal reflux disease but no recent symptoms, 48 respondents (74%) reported using a modified RSI technique. These findings are summarized in Figure 5.

CRNAs also were asked to identify any other patient situations in which they had used a modified RSI technique (Table).

The remaining survey questions addressed the specific components of a modified RSI technique. The
Preoperative administration of medication to alter gastric pH and/or gastrointestinal motility (aspiration pneumonia prophylaxis) was reported by 55 (85%) of the CRNAs who reported using a modified RSI technique. Regarding their choice of drug administration, 52 (95%) of these 55 respondents administered H₂ receptor antagonists, 49 (89%) administered metoclopramide, and 2 (4%) administered sodium citrate. These data are summarized in Figure 6. No other medications were identified as being administered as part of a modified RSI.

Preoxygenation is another key component of standard RSI and possibly of modified RSI. Of the CRNAs who have used a modified RSI technique, 63 (97%) reported that preoxygenation is required before induction. Of those respondents, 61 reported methods (Figure 7), which included preoxygenation on 100% FiO₂ (fraction of inspired oxygen) for 3 to 5 minutes (31 [51%]), for 4 vital capacity breaths (13 [21%]), for fewer than 3 minutes (11 [18%]), and for more than 5 minutes (6 [10%]).

Cricoid pressure is another usual component of both standard and modified RSI. A total of 62 CRNAs (95%) who have used a modified RSI technique reported that the application of cricoid pressure is necessary. Of the respondents (n=57) who reported when cricoid pressure is applied, 40 (70%) reported that cricoid pressure was applied at the same time as administration of the induction agent. Other responses included before administration of the induction agent (11 [19%]), after loss of lid reflex (3 [5%]), and following loss of verbal contact (3 [5%]). These data are summarized in Figure 8.

In standard RSI, positive-pressure ventilation is avoided until the airway is secured. Of those using a modified RSI technique, 61 (94%) reported that an attempt to ventilate via a face mask is appropriate. Of

### Table. Other proposed indications for modified rapid-sequence induction (RSI)*

<table>
<thead>
<tr>
<th>Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient at risk for desaturation but RSI is indicated</td>
</tr>
<tr>
<td>Trauma patient who has been NPO for 8 h</td>
</tr>
<tr>
<td>End-stage renal disease without symptoms of GERD</td>
</tr>
<tr>
<td>Patient for heart surgery with GERD</td>
</tr>
<tr>
<td>Consistent history of reflux</td>
</tr>
<tr>
<td>Patient &gt; 24 h postpartum</td>
</tr>
<tr>
<td>Patient who is &gt; 5 mo pregnant</td>
</tr>
<tr>
<td>Inhalation induction</td>
</tr>
</tbody>
</table>

*GERD indicates gastroesophageal reflux disease; NPO indicates nothing by mouth.

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**Figure 6. Methods of prophylaxis for aspiration pneumonia in modified rapid-sequence induction (n=55)**

<table>
<thead>
<tr>
<th>Method</th>
<th>Percentage of responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium citrate</td>
<td>2 (4%)</td>
</tr>
<tr>
<td>H₂ receptor antagonist</td>
<td>52 (95%)</td>
</tr>
<tr>
<td>Metoclopramide</td>
<td>49 (89%)</td>
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</tbody>
</table>

**Figure 7. Duration of preoxygenation in modified rapid-sequence induction (n=61)**

<table>
<thead>
<tr>
<th>Duration</th>
<th>Percentage of responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 5 minutes</td>
<td>6 (10%)</td>
</tr>
<tr>
<td>3-5 minutes</td>
<td>31 (51%)</td>
</tr>
<tr>
<td>&lt; 3 minutes</td>
<td>11 (18%)</td>
</tr>
<tr>
<td>4 vital capacity breaths</td>
<td>13 (21%)</td>
</tr>
</tbody>
</table>

**Figure 8. Timing of the application of cricoid pressure in modified rapid-sequence induction (n=57)**

<table>
<thead>
<tr>
<th>Timing of cricoid pressure</th>
<th>Percentage of responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before induction agent</td>
<td>11 (19%)</td>
</tr>
<tr>
<td>Same time as induction agent</td>
<td>40 (70%)</td>
</tr>
<tr>
<td>After loss of lid reflex</td>
<td>3 (5%)</td>
</tr>
<tr>
<td>After loss of verbal contact</td>
<td>3 (5%)</td>
</tr>
</tbody>
</table>
the respondents who reported when they attempt to ventilate (n = 60), 30 (50%) reported that they did so both before and after administration of a muscle relaxant. An additional 13 (22%) reported providing positive-pressure ventilation before administration of a muscle relaxant, and 17 (28%) reported providing positive-pressure ventilation following administration of a muscle relaxant. These data are summarized in Figure 9.

**Discussion**

The analysis of the data confirms that a modified RSI technique often is used by CRNAs in clinical practice at 1 institution. As shown in Figure 10, the modified RSI technique most often consists of pharmacological prophylaxis, preoxygenation, cricoid pressure, and positive-pressure ventilation. This differs from a standard RSI technique, which does not include positive-pressure ventilation, and from a routine induction, which does not include aspiration prophylaxis or cricoid pressure.

Although survey respondents were CRNAs with varying experience from inpatient and outpatient settings, the reported use of standard RSI and modified RSI was consistent among all practitioners (Figures 11 and 12). It is important to note that most of the anesthetists surveyed graduated from the same nurse anesthesia training program.

Patients selected for the modified RSI technique included those in whom the relative risks of regurgitation and aspiration seemed to be less than the risks associated with the use of standard RSI. These include moderately obese patients and patients with underlying gastroesophageal reflux disease or a disease process (diabetes, renal failure) associated with gastrointestinal reflux disease but who have no current symptoms. The low reported use of modified RSI for patients with morbid obesity or who have undergone esophageal surgery most likely reflects a tendency to select a standard RSI technique for these patients.

There were some differences among clinicians in the specific application of each component of modified RSI. Variation was demonstrated in the duration of preoxygenation, the timing of application of cricoid pressure, and the choice of preoperative medications to alter gastrointestinal motility and gastric pH. There was wide variation in the timing of positive-pressure ventilation in modified RSI.

Aspiration prophylaxis was reported by most CRNAs as part of a modified RSI. This most commonly consisted of the administration of an H₂ receptor antagonist, metoclopramide, or both.

Preoxygenation with 100% oxygen was provided most often for 3 to 5 minutes and was followed by the application of cricoid pressure. Cricoid pressure generally was applied at the same time as administration of an induction agent. The use of cricoid pressure was reported by nearly all anesthetists as part of a modified RSI technique.

Positive-pressure ventilation is used as part of a modified RSI technique by most CRNAs surveyed. This represents the most substantial difference of modified RSI with standard RSI, in which positive-pressure ventilation generally is avoided. The timing of positive-pressure ventilation in relation to the administration of a muscle relaxant in modified RSI, however, is variable. Some anesthetists reported that they administered positive-pressure ventilation both before and after administration of a muscle relaxant.
Other anesthetists provided positive-pressure ventilation only before or only after administration of a muscle relaxant. A few anesthetists reported that they did not provide positive-pressure ventilation at any time during modified RSI. It is unclear to the investigators how this modified RSI technique differed from standard RSI. The variability in the use of positive-pressure ventilation may represent different objectives for individual patients in the selection of a modified RSI technique. During standard RSI, patients are made apneic and unconscious without establishing that they can be ventilated by mask. This theoretically avoids gaseous distention of the stomach and subsequent possible regurgitation and aspiration. However, if the anesthetist subsequently is unable to intubate or ventilate, results could prove disastrous. During modified RSI, the provision of positive-pressure ventilation via a face mask allows the anesthetist to affirm the ability to ventilate before administering a muscle relaxant. For patients who cannot be ventilated safely via a face mask during modified RSI, a decision can be made before the administration of a muscle relaxant to reawaken the patient and proceed with an awake intubation. This may be of added importance for patients in whom succinylcholine is contraindicated, since the resulting period of paralysis with a nondepolarizing muscle relaxant can be substantially longer.

The modified RSI technique also may be valuable for patients who may not tolerate even brief periods of apnea, because careful, low-peak airway pressure ventilation can be provided throughout the induction period. The use of positive-pressure ventilation before and after the administration of a muscle relaxant allows the anesthetist to test the airway and avoid desaturation.

Modified RSI seems to be an acceptable and common clinical technique for the induction of general anesthesia in selected patients at this institution. Furthermore, the modified technique seems to be well-defined as the sequence of aspiration prophylaxis with an H2 receptor antagonist and metoclopramide, pre-oxygenation with 100% oxygen for 3 to 5 minutes or 4 vital capacity breaths, application of cricoid pressure at the same time as administration of the induction agent, and provision of positive-pressure ventilation before and after administration of a muscle relaxant. As with standard RSI, there seems to be variation in the specific application of each of these components.

The purpose of the present study was to determine whether a modified RSI technique is used in clinical practice for the induction of general anesthesia. Further study is warranted to evaluate the use of a modified RSI technique in other clinical settings and to determine the safety and efficacy of the technique.

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