RESPIRATORY CARE Paper in Press. Published on November 23, 2021 as DOI: 10.4187/respcare.08555

A Scoring Tool That Identifies the Need for Positive-Pressure Ventilation and Determines the Effectiveness of Allocated Respiratory Therapy

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BACKGROUND: Hospital-acquired pneumonia (HAP) and the need for positive-pressure ventilation (PPV) are significant postoperative pulmonary complications (PPCs) that increase patients' lengths of stay, mortality, and costs. Current tools used to predict PPCs use nonmodifiable preoperative factors; thus, they cannot assess provided respiratory therapy effectiveness. The Respiratory Assessment and Allocation of Therapy (RAAT) tool was created to identify HAP and the need for PPV and assist in assigning respiratory therapies. This study aimed to assess the RAAT tool's reliability and validity and determine if allocated respiratory procedures based on scores prevented HAP and the need for PPV. METHODS: Electronic medical record data for nonintubated surgical ICU subjects scored with the RAAT tool were pulled from July 1, 2015–January 31, 2016, using a consecutive sampling technique. Sensitivity, specificity, and jackknife analysis were generated based on total RAAT scores. A unit-weighted analysis and mean differences of consecutive RAAT scores were analyzed with RAAT total scores ≥ 10 and the need for PPV. RESULTS: The first or second RAAT score of ≤ 5 (unlikely to receive PPV) and ≥ 10 (likely to receive PPV) provided a sensitivity of 0.833 and 0.783 and specificity of 0.761 and 0.804, respectively. Jackknifed sensitivity and specificity for identified cut-offs above were 0.800–0.917 and 0.775–0.739 for the first RAAT score and 0.667–0.889 and 0.815–0.79 for the second RAAT score. The initial RAAT scores of ≥ 10 predicted the need for PPV (*P* < .001) and was associated with higher in-hospital mortality (*P* < .001). Mean differences between consecutive RAAT scores revealed decreasing scores did not need PPV. CONCLUSIONS: The RAAT scoring tool demonstrated an association with the need for PPV using modifiable factors and appears to provide a quantitative method of determining if allocated respiratory therapy is effective. *Key words: postoperative pulmonary complications; misallocation of therapy; respiratory care protocols; outcomes; prediction tools.* [Respir Care 0;0(0):1–•. © 0 Daedalus Enterprises]

Introduction

The occurrence of postoperative pulmonary complications (PPCs) has been reported at 2–40% in surgery patients, with the highest occurrences in thoracic (37.8%) and upper abdominal (12.2%) surgeries.[1,2] Mortality for postoperative pneumonia ranges from 16.5–25.5% and for unplanned intubations ranges from 24.8–38.4%.[3] Pneumonia and unplanned intubations have been reported to increase the cost per admission from $12,000–$27,000 and $12,000–$120,000, respectively.[1] If extrapolated to the United States population, PPCs would account for over $3 billion in additional costs.[3]

There have been numerous prediction scoring tools created to identify risk factors for developing pulmonary complications. Some of these scoring tools focus on thoracic,[4-6] esophageal,[7,8] or abdominal[9] surgeries, whereas others have assessed general surgical cohorts[10-14] or particular pulmonary complications such as pneumonia[15] or respiratory failure.[12,13,16-21] Most of these scoring tools are preoperative assessments. The identified risk factors can be separated into modifiable and nonmodifiable factors.[1,22] Examples of modifiable factors include obesity, smoking status, anemia, and current respiratory infection, whereas nonmodifiable factors would consist of congestive heart failure, COPD, diabetes mellitus, and advanced age.[1,22] These lists are not exhaustive, but very few of these factors can be modified in a short period of time.

Currently, the use of respiratory therapy to prevent pulmonary complications is controversial. Surgical clinical guidelines support the use of lung expansion therapy to reduce the risk of developing pulmonary complications.[23] Based on current evidence, the routine use of lung expansion therapy (incentive spirometry [IS]), chest physiotherapy therapy, positive expiratory pressure [PEP], or intermittent positive-pressure breathing [IPPB] is not recommended to prevent pulmonary complications.[24-27] The American Association for Respiratory Care clinical practice guideline also does not support the routine use of lung expansion techniques.[28] However, other combinations of respiratory care such as IS, coughing, deep breathing, oral care, patient education, early mobility, and head-of-bed elevation have successfully reduced the incidence of PPCs.[29] A metric to assess the patients' responsiveness to targeted respiratory therapy postoperatively is needed.

To address this issue, we developed the Respiratory Assessment and Allocation of Therapy (RAAT) tool. This tool was designed to identify patient findings that may lead to major pulmonary complications and assist in allocating respiratory therapy. This study aimed to assess the reliability and validity of the RAAT scoring tool and determine if the allocation of respiratory procedures based on RAAT scores in nonintubated ICU subjects was effective.

QUICK LOOK

Current knowledge

Postoperative pulmonary complications (PPCs) increase patient mortality and costs. Current tools used to predict PPCs use nonmodifiable preoperative factors that limit their use to determine if allocated respiratory therapy is working effectively.

What this paper contributes to our knowledge

A scoring tool, the Respiratory Assessment and Allocation of Therapy (RAAT) tool, demonstrated that scores ≥ 10 were associated with the need for positive-pressure ventilation (PPV) and higher mortality in post-operative subjects. The RAAT tool also uses modifiable factors in its scoring, and analysis revealed that subjects with decreasing scores did not receive PPV. Thus, the RAAT scoring tool may provide a quantitative method of determining if allocated respiratory therapy is effective.

Methods

RAAT Scoring Tool

The RAAT tool was designed to identify patient findings associated with major pulmonary complications, hospital-acquired pneumonia (HAP), and need for PPV. Unplanned intubations and use of noninvasive ventilation (NIV) due to respiratory failure were grouped together and defined as need for PPV. The RAAT scoring tool resulted in a total score based on 5 respiratory-related components: respiratory distress, chest x-ray, oxygen therapy, secretion clearance, and vital capacity in nonintubated spontaneously breathing subjects (See Fig. 1). Each of these components received a score of 0, 5, or 10 depending on the severity of these findings. The maximum achievable score would be 50. In addition, if the chest radiograph revealed pulmonary edema, pleural effusion, or pneumothorax, the therapist was directed to "STOP" and contact the physician regarding these findings.

The RAAT tool was piloted in 149 surgical and medical ICU subjects who were scored prospectively. Then respiratory therapy and pulmonary complication data were collected retrospectively. Subjects with a RAAT score ≥ 10 were more likely to develop HAP (P = .02) and need for PPV (P =.001) compared to subjects whose score was ≤ 5. Physician-directed respiratory therapy was provided to 78% (39/50) of the subjects with a RAAT score ≥ 10 and 57% (56/99) of the subjects who scored ≤ 5. Based on this observation, medical provider-ordered therapy was considered misallocated.[30] A quality improvement project was then implemented clinically to assist respiratory therapists in allocating respiratory therapy based on a series of protocols linked to the RAAT scoring tool.

Quality Control Project Overview

Retrospective data from a quality improvement project targeted at improving the allocation of respiratory therapy to prevent pulmonary complications in nonintubated subjects in a surgical ICU (SICU) at an urban academic medical center were used in this manuscript. Rush's Institutional Review Board approved the use of these retrospective data.

All SICU subjects were scored within 2 h of admission to the unit or extubation. Subjects were scored again

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Dr Vines reports relationships with Theravance Biopharma, Teleflex Medical, and the Rice Foundation. Dr Scott discloses a relationship with Teleflex Medical. The remaining authors have disclosed no conflicts of interest.

A version of this paper was presented at the American Thoracic Society 2020 International Conference held in Philadelphia, Pennsylvania, May 15–20, 2020.

The study was funded by the department.

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DOI: 10.4187/respcare.08555

RESPIRATORY CARE Paper in Press. Published on November 23, 2021 as DOI: 10.4187/respcare.08555

Rush RAAT score

1. Respiratory distress	0	No signs of distress
	5	Frequency ≥25 breaths/min, complaint of SOB on exertion
	10	Frequency ≥30 breaths/min and labored breathing (accessory muscle use, paradoxical breathing), and/or S_{pO_2} decline ≥5% from the last value recorded
2. Chest x-ray	0	Normal
	5	Lobar atelectasis or pneumonia
	10	Complete atelectasis, partial atelectasis after pneumonectomy, pneumonia of entire lung, bilateral pneumonia
	STOP	Pulmonary edema, large pleural effusion, pneumothorax Contact physician/consider alternative therapy
3. Oxygen therapy	0	F_{IO_2} ≤ 0.4
	5	F_{IO_2} > 0.4 - 0.6
	10	F_{IO_2} > 0.6
4. Secretion clearance	0	Clear to auscultation, dry, non-productive cough
	5	Coarse crackles (rhonchi) resolved after cough/suctioning
	10	Coarse crackles (rhonchi) heard continuously, not resolved after cough/suctioning
5. Spontaneous Vital Capacity (based on IBW) obtained via IS or respirometer	0	≥15 mL/kg
	5	8-15 mL/kg
	10	< 8 mL/kg

RAAT Total score: _______ Actual mL/kg: _________/Effort OK?_____
Current RT order (if any):

Fig. 1. Rush Respiratory Assessment and Allocation of Therapy (RAAT) scoring tool. SOB = shortness of breath, IBW = ideal body weight, IS = incentive spirometry, RT = respiratory therapy.

approximately 12 h after the first scoring. Subject scoring and therapy allocation continued until 2 consecutive RAAT scores ≤ 5 were obtained or the subjects were discharged from the unit. After each scoring, a progress note was entered indicating each component score, the total RAAT score, and respiratory therapy plan of care for the surgical teams to review.

To assist respiratory therapists in the allocation of therapy, protocols (lung expansion, airway clearance, and oxygen therapies) were created and linked to the RAAT scoring tool. They were based on the authors' expert opinion and clinical practice guidelines and approved by the department's and SICU medical directors. RAAT scores and these protocols guided the respiratory therapy provided to the subjects. Respiratory therapists could escalate therapy if the RAAT score increased or deescalate therapy if the RAAT score decreased.

Reliability of the RAAT Tool

Before initiating this project, respiratory therapists were trained to score subjects using this tool and allocate therapy based on the protocols. Once initial training was completed, the RAAT tool's reliability was determined from a test-retest design in our institution's simulation center using a human patient simulator (CAE Healthcare, Sarasota, Florida). Four simulated cases were developed. In an alternating fashion, therapists were assigned to score the simulated cases, which resulted in predetermined total RAAT scores of 5 and 30 or 25 and "STOP." If a STOP was due to the finding of pulmonary edema, pleural effusion, or pneumothorax on chest radiograph, they stated that a physician would be contacted to report the findings. Each staff respiratory therapist scored 2 simulated cases on week 1 and returned a week later to retest the same 2 simulated cases. The names of the retest cases

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were changed to give the impression that these cases were different. All test-retest affected cases were administered by the department's education coordinator.

Validation of the RAAT Tool and Allocation of Therapy

RAAT scoring and allocation of therapy based on the care algorithms began on July 1, 2015. Retrospective data used to assess the RAAT tool's effectiveness were collected through January 31, 2016, using consecutive sampling. Subjects were included if ≥ 18 y of age, not intubated, and in SICU long enough to receive 2 RAAT scores or require PPV after the first score. Subjects were excluded if they received one RAAT score and were discharged from SICU or required extracorporeal membrane oxygenation.

Data were collected from the electronic medical record and stored in a secure electronic database, REDCap (Version 6.18.1, Vanderbilt University). The following data were acquired: age, sex, current smoker, body mass index (BMI), ICU admission, mortality, diagnosis, total RAAT scores, RAAT component scores, vital capacity measures, allocated and documented respiratory therapy procedures, HAP, and need for PPV either noninvasive or invasive. Subjects were considered a current smoker if they quit within 30 days of surgery or were still smoking. HAP was determined by physician diagnosis in the electronic medical record. Need for NIV was determined from the documented use in electronic medical record for purposes other than obstructive sleep apnea. Need for invasive PPV was identified by the intubation procedure note in the electronic medical record.

Statistical Analysis

Categorical data were compared using chi-square tests. Need for NIV or invasive PPV was combined into one group labeled need for PPV to increase the sample size for this complication. To access reliability, intraclass correlations (one-way random effects) were calculated for the therapists rating each of the 4 simulated cases. Test-retest data were reported as a correlation for the 4 cases.

Receiver operating characteristic (ROC) curves were generated for the first and second RAAT scores related to the need for PPV. The ROC results were analyzed using a jackknife analysis to examine the level of robustness.

A unit-weighted analysis of consecutive RAAT scores was performed to create a linear model of prediction with RAAT total scores ≥ 10 and the need for PPV. Kendall τ-b tests were performed on the weighted data to determine significance ($P < .05$).

To assess allocated therapy effectiveness, 3 consecutive total RAAT scores and measured vital capacities were analyzed using the Friedman test in subjects with a RAAT score ≥ 10 and receiving any respiratory therapy. If a difference ($P < .05$) was found, a Wilcoxon signed-rank test was performed to determine which of the 3 measures were different. A P value < .017 was considered significant to control for family-wise error. Subjects whose RAAT score was ≥ 10 who received therapy differences between the first 3 consecutive total RAAT scores were calculated for 2 groups, those who did and did not need PPV. These mean differences were compared using independent t tests to determine differences ($P < .05$).

Results

Reliability of the RAAT Tool

Intraclass correlations for cases 1 and 2 indicated an average between 26 therapists of 0.999 with a 95% CI 0.9–1.0. Intraclass correlation for cases 3 and 4 indicated an average between 28 therapists of 0.999 with 95% CI 0.9–1.0. Test-retest reliability of the RAAT tool was established with 29 registered respiratory therapists scoring 4 simulated cases. Six of the 29 therapists failed to return to rescore simulated cases after the initial scoring. Twelve of 12 therapists (100%) rescored case 1 (STOP, contact physician) correctly. Ten of 12 therapists (83%) rescored case 2 (RAAT total score 25) correctly. Ten of 11 therapists (91%) rescored case 3 (RAAT total score 5) correctly. Eleven of 11 therapists (100%) rescored case 4 (RAAT total score 30) correctly.

Sensitivity and Specificity of the RAAT Tool

Figure 3 exhibits the ROC curve for using the first total RAAT score to predict the administration of PPV. The Figure 3 shows a large (0.841) area under the curve (AUC), and by selecting a cutoff between a score 5–10 (where subjects with a score ≤ 5 are unlikely to receive PPV and subjects with a score ≥ 10 are more likely), a sensitivity of 0.833 and specificity of 0.761 were obtained. Similar findings were observed for the second total RAAT score. Its AUC was 0.821, and selecting a cutoff between a score ≤ 5 (unlikely to need PPV) and ≥ 10 (likely to need PPV), a sensitivity of 0.783 and specificity of 0.804 were found. The ROC results were analyzed using a jackknife analysis. The jackknifed AUC for the first RAAT score was 0.829–0.859 (sensitivity of 0.800–0.917, specificity of 0.775–0.739) and for the second RAAT score was 0.778–0.899 (sensitivity of 0.667–0.889, specificity of 0.815–0.790).

Sample Used for Validation of the RAAT Tool and Associated Protocols

A sample of 658 subjects was scored with the RAAT tool in the SICU between July 1, 2015–January 31, 2016. Seventy-three patients were excluded. See Figure 2. Of the 585 subjects who remained, 391 had a RAAT score ≤ 5,

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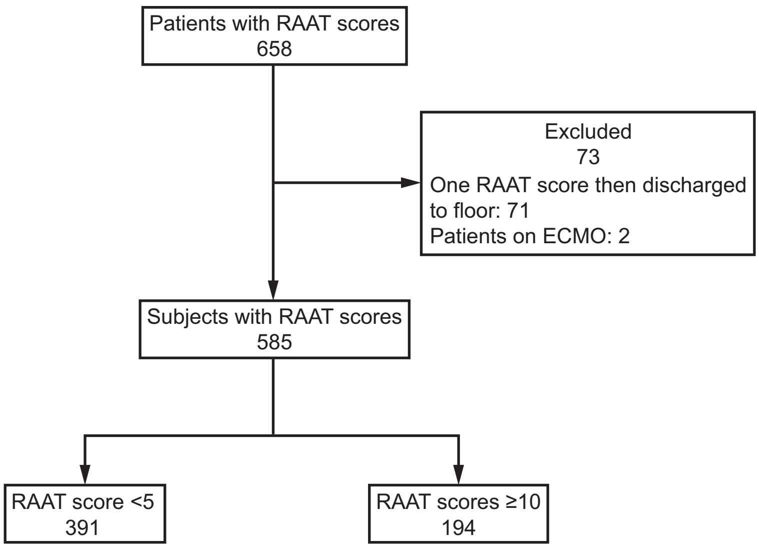

Fig. 2. Flow chart. RAAT = Respiratory Assessment and Allocation of Therapy, ECMO = extracorporeal membrane oxygenation.

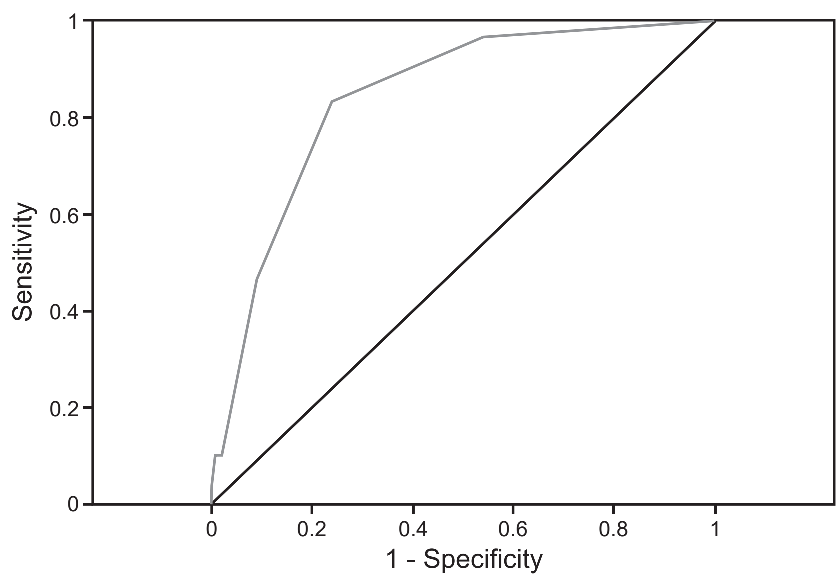

Fig. 3. Receiver operating characteristic (ROC) curve for first Respiratory Assessment and Allocation of Therapy (RAAT) scores and need for invasive or noninvasive positive-pressure ventilation (PPV). These ROC curves were generated to determine their sensitivity and specificity related to the nonintubated SICU subjects' need for PPV. The first RAAT score was collected within 2 hours of admission. The second score was approximately 12 hours later. The area under the curve for the first RAAT score was 0.84. Coordinates of the curve identified the score of 10 as having the highest sensitivity and specificity (0.833 and 0.761, respectively).

whereas 194 had a RAAT score ≥ 10. Fifteen of the 30 subjects needed PPV within approximately 24 h after admission or extubation. Table 1 provides demographic and clinical characteristics for subjects whose total RAAT scores were ≤ 5 or those who had a total RAAT score ≥ 10. There were no differences in gender, BMI, or smoking status between these groups.

Outcomes and Prediction of the Need for PPV Based on RAAT Scores

Initial RAAT scores ≥ 10 were more likely to need PPV ($P < .001$) and were associated with higher in-hospital mortality ($P < .001$). The occurrence of HAP was too low to assess. See Table 1. The unit-weighted analysis revealed that

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Table 1. Characteristics of Surgical Subjects Scored With the Respiratory Assessment and Allocation of Therapy Tool

Variable	First and Second RAAT Score ≤ 5 (n = 391)	First or Second RAAT Score ≥10 (n = 194)	P
Demographics			
Male, no. (%)	207 (53)	108 (56)	.53
Age (mean ± SD)	61 ± 15	64 ± 15	.047
Body mass index (mean ± SD)	29 ± 12	30 ± 8	.17
Current smoker (n, %)	53 (14)	32 (17)	.36
Classification of surgical subjects (n, %)			
Liver failure/transplant	21 (5)	13 (7)	.32
Upper-airway cancer/surgery	27 (7)	6 (3)	.060
Lung cancer/surgery	29 (7)	35 (18)	< .001
Renal failure/kidney transplant	44 (11)	10 (5)	.02
Peripheral vascular disease/surgery	50 (13)	3 (2)	< .001
Spinal disorder/surgery	36 (9)	4 (2)	.001
Other cancer(abdomen, bone, breast, renal)	34 (9)	15 (8)	.69
Neurologic disorders/brain cancer	11 (3.0)	1 (0.5)	.054
Cardiovascular disorders/surgery	77 (20)	73 (38)	< .001
General surgery (abdominal, joint replacement)	62 (16)	34 (18)	.61
Outcomes (n, %)			
Need for PPV (invasive or noninvasive)	3 (1)	27 (14)	< .001
Hospital-acquired pneumonia	0	1 (0.5)	.16
In-hospital mortality	10 (3)	18 (9)	< .001
Respiratory therapy provided (n, %)			
Any treatment given in the first 24 h	116 (30)	182 (94)	< .001
IS therapy	115 (29)	142 (73)	< .001
IPPB therapy	2 (0.5)	54 (28.0)	< .001
Vibratory PEP therapy	4 (1)	42 (22)	< .001
CPT	2 (0.5)	4 (2.0)	.97
HFCWP	2 (0.5)	7 (4.0)	.008
IPV therapy	5 (1)	9 (5)	.02

RAAT = Respiratory Assessment and Allocation of Therapy
PPV= positive pressure ventilation
IS = incentive spirometry
IPPB = intermittent positive-pressure breathing
PEP = positive expiratory pressure
CPT = chest physiotherapy
HFCWP = high-frequency chest wall percussion
IPV = intrapulmonary percussive ventilation

Table 2. Unit-Weighted Analysis* Respiratory Assessment and Allocation of Therapy Scores Versus Need for Positive-Pressure Ventilation in 585 Subject

RAAT Scores ≥ 10	Need for PPV – Yes (n, %)
0 n = 392	(3, 1)
1 n = 100	(12, 12)
2 n = 93	(15, 16)
Kendall τ-b = 0.28, P < .001	

* A unit-weighted analysis of consecutive RAAT scores was performed to create a linear model of prediction with RAAT total scores ≥ 10 and the need for PPV. If the patient's first or second RAAT scores was < 10, they received a 0. If the first or second RAAT score was ≥ 10, they received a 1. If both the first and second RAAT score was ≥ 10, they received a 2. Then chi-square and Kendall τ-b tests were performed on the weighted data.
RAAT = Respiratory Assessment and Allocation of Therapy
PPV = positive-pressure ventilation

the RAAT scores ≥ 10 within the first 24 h predicted the need for PPV (Kendall τ-b = 0.28, P < .001). See Table 2.

RAAT Scoring Tool and Associated Protocols Effect on Allocation of Therapy

Allocation of respiratory therapy using RAAT scores was much lower (P < .001) in subjects with RAAT scores ≤ 5. Thirty percent of the subjects with a RAAT score ≤ 5 received treatments, of which 29% were given IS. Ninety-four percent of subjects with RAAT scores ≥ 10 received therapy, and more of these subjects received IPPB for lung expansion and vibratory PEP therapy for airway clearance. See Table 1.

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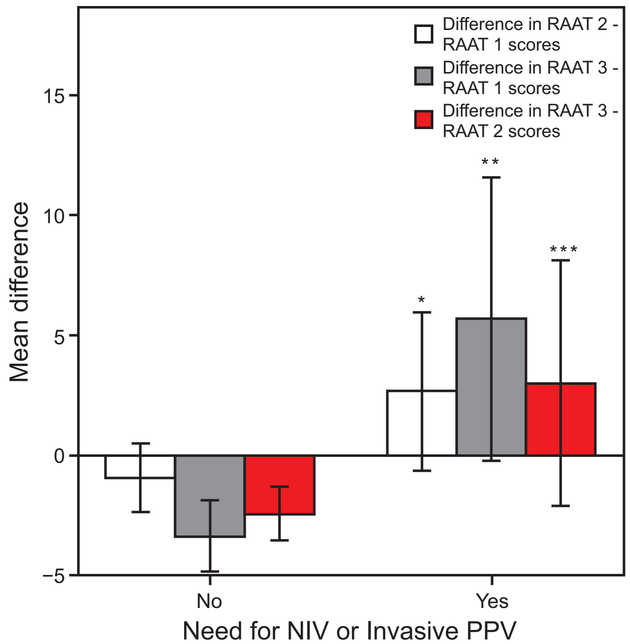

Fig. 4. Mean changes in Respiratory Assessment and Allocation of Therapy (RAAT) scores between subjects receiving treatments with a RAAT score ≥ 10 and need for positive-pressure ventilation. NIV = noninvasive ventilation, PPV = positive-pressure ventilation. *Significantly (P = .03) higher than corresponding mean difference in RAAT 1 and 2 in subjects not needing PPV. ** Significantly (P = .006) higher than corresponding mean difference in RAAT 1 and 3 in subjects not needing PPV. *** Significantly (P = .042) higher than corresponding mean difference in RAAT 2 and 3 in subjects not needing PPV.

Allocated Therapies Effect on Subsequent RAAT Scores and Vital Capacity

Allocation of respiratory procedures based on RAAT scores ≥ 10 using therapist-driven protocols resulted in a third total RAAT score (10; interquartile range [IQR] 5–15) being lower compared to the first (10; IQR 10–15) and second RAAT scores (10; IQR 5–15). Median measured vital capacity for the second (11 mL/kg; IQR 8–13) and third (12 mL/kg; IQR 9–15) RAAT scores was higher than the vital capacity from the first (9 mL/kg; IQR 7–12) RAAT score. Median measured vital capacity for the third RAAT score was also higher than the second RAAT score.

Allocated Therapies Effect on Subsequent RAAT Scores in Subjects Who Did and Not Need PPV

RAAT scores that were ≥ 10 and receiving treatments were separated into 2 groups, those who needed PPV and those who did not. Mean differences between the second-first, third-first, and third-second RAAT scores were 2.8 ± 6.9, 5.7 ± 10.7, and 3.0 ± 9.2, respectively, for the group needing PPV. Mean differences between the second-first, third-first, and third-second RAAT scores were −1.3 ± 7.5, −3.3 ± 8.0, and −2.4 ± 6.0, respectively, for the group not needing PPV. These differences were significant. See Figure 4.

Discussion

As observed in pilot data,[30] our findings indicate that subjects with a RAAT score ≥ 10 were more likely to need PPV and a RAAT score ≤ 5 were unlikely to need PPV. RAAT scores ≥ 10 were also associated with increased in-hospital mortality. Linear modeling found that the first and second RAAT scores ≥ 10 were predictive of needing PPV. After training, the consistency between raters and repeatability in a group of registered respiratory therapists using the RAAT tool was high. An important finding in subjects receiving respiratory therapy was that increasing mean differences in RAAT scores were associated with the need for PPV, whereas decreasing differences were not.

Sensitivity and specificity of the RAAT tool were best at ≥ 10 as the cutoff to determine subjects at risk of needing PPV. The AUCs were similar for both first and second RAAT scores, and jackknifed analysis confirmed the robustness of these data. Of the 391 subjects that score ≤ 5, 3 subjects scoring a 5 required PPV. All 3 subjects were scored more than 5 h before their documented need for PPV. These subjects had issues with becoming acutely unarousable or inability to cough up secretions, resulting in desaturations. Acute deteriorations due to isolated incidents such as oversedation would likely not be identified unless patients are rescored after sedation is given.

Other predictive tools have been developed to identify respiratory failure with similar sensitivity and specificity as the RAAT scoring tool.[12,13,16-21] These scoring tools are preoperative assessments, and the risk factors identified are not modifiable, such as type of surgery,[12,13,16,21] emergency surgery,[12,13,16-18,21,31] dependent functional status,[16,18,20] older age,[16,17,19,21,31] COPD,[13,16,20,21,31] congestive heart failure,[12,13,17] American Society of Anesthesiologist classification of a patient with severe systemic disease,[13,18-20] and preoperative sepsis.[18,19] Factors that have been identified as modifiable factors such as obesity, smoking, alcohol intake, low serum albumin, anemia, low oxygen saturation, current respiratory infection, and surgery longer than 3 h[1,22] delay surgery and may not be easily corrected. The RAAT tool is scored postoperatively and utilizes 5 components that are modifiable with appropriate respiratory therapy.

The FLAM score is another scoring tool used postoperatively in thoracic patients to determine their risk of developing PPCs.[4] They created an elaborate scoring scheme that assesses the level of dyspnea, chest x-ray, delivered oxygen, breath sounds, cough effectiveness, amount of bronchial secretions, and purulence of the secretions in an ordinal manner. A FLAM score of 9 provided the best

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sensitivity and specificity (AUC 0.97).[4] Whereas most of these factors are modifiable, the FLAM scoring tool is difficult to score, has not been validated in a larger surgical population, and does not suggest a patient care strategy to prevent pulmonary complications. This report provides validation of the RAAT scoring tool in a larger surgical population. It also has a series of affiliated protocols that allows for escalation of therapy if the score worsens.

The RAAT scoring tool and associated therapist-driven protocols resulted in allocating respiratory therapy to subjects likely to develop respiratory failure. A significant number of these subjects received multiple therapies. The RAAT score and associated therapist-driven protocols allowed respiratory therapists to tailor therapies targeted at the underlying pathophysiology in an effort to prevent the need for PPV. While not indicated based on the RAAT score, 29% percent of the subjects scoring ≤ 5 received IS therapy. Some clinicians would consider IS therapy to be standard of care.[23] In the RAAT scoring tool, IS serves as an indicator of the patients' progress in gaining respiratory muscle strength and ability to follow commands. IS should be thought of as a monitoring tool.

In subjects receiving therapy, the mean difference in RAAT scores illustrated in Figure 4 best demonstrates RAAT scores and associated therapist-driven protocols effectiveness. When mean differences were increasing, subjects were likely to need PPV, whereas subjects with decreasing differences did not. Therefore, if RAAT scores are increasing, respiratory therapy should be escalated. For example, if a patient receives IS and their vital capacity is ≤ 8 mL/kg or less, the therapy should be escalated to IPPB with a volume target at 15 mL/kg. If RAAT scores are decreasing, then frequency or type of therapy should be de-escalated and then discontinued after 2 consecutive RAAT scores ≤ 5. The RAAT tool appears to provide a measure to determine therapy effectiveness when used in this manner.

The use of respiratory therapy to prevent pulmonary complications remains controversial. A few clinical trials support the routine allocation of IS therapy to prevent pulmonary complications.[32-34] Although multiple trials provide evidence that routine allocation of IS should not be recommended,[25,26,35-38] several of these trials compare IS to deep breathing or PEP, which are other lung expansion methods.[25,35,37,38] If patients can perform various lung expansion techniques correctly, clinical findings should be similar. Most of these studies also included ambulation in both the control and experimental groups,[25,26,35-37] which questions the subjects' level of distress and severity.

In this study, subjects with lobar atelectasis would not receive treatment unless this finding was accompanied by the need for 40% oxygen or more, breathing frequency of 25 breaths/min with some distress, or a vital capacity measured on IS of < 15 mL/kg. Fifty percent of the subjects needing PPV only received 3 RAAT scores, demonstrating the severity of subjects in this study. This finding suggests the need for timely escalations of respiratory therapy to prevent the need for PPV.

Cassidy et al[29] have suggested and demonstrated that a multidisciplinary patient care program combining IS, coughing, deep breathing, oral care, patient education, early mobility, and head-of-bed elevation can successfully reduce pulmonary complications. This multifaceted approach requires considerable staffing resources. Multiple aspects of this program should be routinely included in ICU patient care, such as earlier mobility, coughing, oral care, and head-of-bed elevated. Unlike the RAAT scoring tool and respiratory therapist-driven protocols, this multifaceted system does not provide clinicians with a recommended direction. We also want our staff to focus on those patients who will potentially benefit the most and not utilize supplies and therapist time to provide respiratory therapy to all patients. The RAAT scoring tool and associated protocols allocate respiratory therapy based on patients' clinical findings. Respiratory therapists can write progress notes containing RAAT scores, established therapeutic goals, and scheduled therapy procedures. The protocols incorporate reminders of limitations associated with each type of therapy, such as avoidance of PEP therapy in patients unable to generate a vital capacity of 12 mL/kg. Lung expansion therapy was also targeted to increase the vital capacity to 15 mL/kg. These nuances, respiratory therapists' training and familiarity with the therapies and equipment, and RAAT tool, are strengths of this system.

There are several limitations to this study. Whereas the validity of the scoring tool can be established, this retrospective data limit the ability to draw conclusions on the effectiveness of the individual therapies or protocols used in this study. Another limitation is the difficultly of assessing the therapists' timely adherence to escalating therapy. This limitation has been addressed through feedback and developing annual competencies with case discussions requiring therapists to demonstrate their ability to use approved protocols. An additional limitation is that subjects who scored ≤ 5 could have continued to use the IS after their initial training. IS was documented in 30% of subjects with a low RAAT score, indicating staff reliance on this therapy even when not clinically indicated. This bias may have also limited the escalation of therapy in a timely manner.

The goal of this RAAT scoring tool and associated protocols is to move the profession from being task oriented to one focused on initiating timely decisions by adjusting therapy to achieve patients' therapeutic goals, prevent the need for PPV, and communicate with the health care team. More research is required to determine the RAAT scoring tool's effectiveness in other patient populations, such as neurosurgery and medical patients. More randomized controlled

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trials are needed to evaluate individual therapies and protocols for preventing pulmonary complications and improving patient outcomes.

Conclusions

Subjects with a RAAT score ≥ 10 were more likely to need PPV, whereas those with a RAAT score ≤ 5 were unlikely to need PPV. RAAT scores ≥ 10 were also associated with increased in-hospital mortality. The RAAT scoring tool's use of modifiable factors linked to therapist-driven protocols may provide a quantitative method of determining the effectiveness of assigned respiratory therapy. Further prospective clinical trials are needed to determine if the RAAT scoring tool and therapist-driven protocols can increase respiratory care services' value by improving patient outcomes and reducing misallocation of therapy.

ACKNOWLEDGMENTS

We would like to acknowledge the respiratory therapists at Rush University Medical Center for the outstanding work that they do to improve patient outcomes.

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