

# Effectiveness of intrahospital transportation of mechanically ventilated patients in medical intensive care unit by the rapid response team

## A cohort study

Won Gun Kwack, MD<sup>a,b</sup>, Miae Yun, RN<sup>b</sup>, Dong Seon Lee, RN<sup>b</sup>, Hyunju Min, RN<sup>b</sup>, Yun Young Choi, RN<sup>b</sup>, Sung Yoon Lim, MD, PhD<sup>a,b</sup>, Youlim Kim, MD<sup>a,b</sup>, Sang Hoon Lee, MD, PhD<sup>a</sup>, Yeon Joo Lee, MD<sup>a,b</sup>, Jong Sun Park, MD, PhD<sup>a</sup>, Young-Jae Cho, MD<sup>a,b,\*</sup>

### Abstract

Critically ill patients could experience various risks including life-threatening events during intrahospital transportation (IHT), with a global incidence of 20% to 79.8%. Evidence on the clinical benefits of the presence of specialized intensive care members such as the rapid response team (RRT) during their transportation is limited. We aimed to elucidate the RRT's effectiveness in promoting patient's safety outcomes during transportation by comparing with those transport by general members.

A single-center retrospective cohort study was conducted from January 2016 to February 2017, including critically ill patients admitted to the medical intensive care unit (ICU) due to respiratory failure under mechanical ventilation. Patients who underwent out-of-ICU transportation supported by RRT members, including a portable ventilator, were categorized as the RRT group, whereas those transported by general members, such as residents or interns, were the general group. Propensity score matching (PSM) was conducted due to several significant differences in the baseline characteristics between the 2 groups. Adverse events were defined as any situation requiring cardiopulmonary resuscitation (CPR), any physiologic deteriorations requiring immediate intervention or equipment dysfunctions.

The median age of the 184 subjects included was 72 (inter quartile range, 62–75) years, and 114 (62.3%) of them were male. Thirty-six (19.6%) transports were supported by RRT, with significant higher APACHE II score than general groups ( $36.7 \pm 6.0$  vs  $32.4 \pm 7.7$ ,  $P = .002$ ). There was no critical event requiring CPR in both groups. However, adverse events were more frequently observed in the RRT than the general group (27.8% vs 8.1%,  $P = .001$ ). PSM revealed insignificant difference in adverse events (26.7% vs 10.0%,  $P = .228$ ).

In critically ill patients in the medical ICU, IHT supported by the RRT did not show a more preventative effect on adverse events than that by the general group.

**Abbreviations:** APACHE II = acute physiology and chronic health evaluation II, ICU = intensive care unit, IHT = intrahospital transportations, PaCO<sub>2</sub> = partial pressure of arterial carbon dioxide, PF ratio = ratio of arterial oxygen partial pressure to fractional inspired oxygen, PICC = peripherally inserted central catheter, PSM = propensity score matching, RRS = rapid response system, RRT = rapid response team.

**Keywords:** critically ill, medical intensive care unit, patient safety, rapid response team, transportation

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<sup>a</sup> Division of Pulmonary and Critical Care Medicine, Department of Internal Medicine, <sup>b</sup> Rapid Response Team, Interdepartment of Critical Care Medicine, Seoul National University Bundang Hospital, 173-82 Gumi-Ro, Bundang-Gu, Seongnam, Gyeonggi-Do, Republic of Korea.

\* Correspondence: Young-Jae Cho, Division of Pulmonary and Critical Care Medicine, Department of Internal Medicine, Seoul National University College of Medicine, Seoul National University Bundang Hospital, 173-82 Gumi-Ro, Bundang-Gu, Seongnam, Gyeonggi-Do 13620, Republic of Korea (e-mail: lungdrcho@gmail.net).

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## 1. Introduction

Critically ill patients inevitably experience a considerable number of intrahospital transportations (IHTs) for their diagnostic examinations or therapeutic interventions,<sup>[1]</sup> with previously reported out of intensive care unit (ICU) transport rates of 22.5% to 52.4%.<sup>[2–4]</sup> During IHT, patients may be unstable, and these situations can result in various harmful clinical outcomes or medical errors and even cause severe critical events such as death. Previous studies revealed that the overall incidence of adverse events ranged from 20% to 79.8%, of which serious adverse events requiring therapeutic intervention range from 4.2% to 8.9%.<sup>[5–7]</sup>

The most obvious way to reduce the risk related to IHT is reducing IHT itself. However, in practice, patient transportation cannot be completely avoided because all diagnostic and therapeutic procedures could not be done at the bedside. Moreover, 26.7% of IHT also changed their treatment plan.<sup>[8]</sup> Therefore, understanding risk factors associated with complications related to IHT is important to guarantee the benefit of IHT and to determine appropriate solutions.

Among many factors affecting as the risk of adverse events in IHT, 4 categories have been considered: patient state, equipment, transport indication and organization, and composition of transport team.<sup>[9]</sup> As the perception on the risks of IHT is increasing, developing standard care system such as precheck list and homogenization of implemented modalities has partly contributed to the reduction in the incidence of adverse events. Unfortunately, data on pre- and interhospital transportation are merely available; however, data on IHT are extremely limited.

This study focused on the transport team member's level of competence on the possible risk factors. We elucidated whether IHT in critically ill patients accompanied by the rapid response team (RRT) including well-trained-nurses influenced patient's safety outcomes by comparing them with those transport by general members.

## 2. Methods

A retrospective cohort study was conducted on respiratory failure patients under mechanical ventilation who were admitted in medical ICU in a tertiary academic hospital, from January 2016 to February 2017. All IHTs for diagnostic and therapeutic purposes supported by RRT or general members were analyzed based on the electronic medical record. Patients without endotracheal tube and tracheostomy tube and with lack of clinical information were excluded. When several time transports were performed during a single hospital stay, only the 1st time transport was included. Subjects transported to other departments, such as general ward or other ICUs after achieving transport goal, were excluded. Subjects transported to the operating room were also excluded because patient monitoring and management was taken over by different medical staffs. The transport and composition of transfer team were decided based on the judgment of the attending intensivist depending on patient condition. General members consist of interns or residents with transport assistants who supported patient's bed upon IHT and use a manual resuscitator, whereas RRT includes well-trained nurse in addition to general members and use of a portable ventilator (Hamilton-C1; Hamilton medical Inc, Bonaduz, Switzerland). In all transports, the number of RRT and general group members were 3 and 2, respectively.

Our hospital has operated with rapid response system (RRS) since October 2012. RRS team has a role to timely detect and manage deteriorating patients in general wards by screening systems and direct calling for request. The RRS team is composed of physicians and well-trained nurse with >5 years of ICU experience and the completion of critical care nursing process. We hold weekly meetings for case and journal reviews to educate RRS members. Our RRS has been reported to reduce the number of cardiopulmonary arrests.<sup>[10]</sup> RRS nurses were in charge for IHT in suspected unstable patients, upon request.

The duration of IHT was defined as the whole duration from departure to return to the ICU including that spent in diagnostic and therapeutic procedures. This study's outcomes were the number of adverse events. The adverse events were one of the following situations: cardiopulmonary resuscitation, physiologic parameter change that urgently need intervention by the transport team; hypotension or hypertension ( $\geq 20\%$  change from pretransport), bradycardia or tachycardia ( $\geq 20\%$  change from pretransport) and desaturation ( $\geq 5\%$  reduction in pulse oximeter saturation); irritability requiring sedation drug; endotracheal tube or tracheostomy tube dislodgement; and dislodgement of central or peripheral line. Other data including age, sex,

comorbidities, type of transport (diagnostic/therapeutic), destination, requiring transport time, pretransport vital sign and laboratory values, acute physiology and chronic health evaluation (APACHE) II within 24 hours after ICU admission, inotropes or sedatives required, and ICU length of stay before transport were recorded. The Institutional Review Board (IRB) of Seoul National University Bundang Hospital approved the study protocol (IRB no: B-1709-423-103) and which waived the need for informed consent because of the retrospective study design in accordance with the Declaration of Helsinki.

Continuous variables are expressed as means and standard deviation, or median and interquartile range (IQR). Categorical variables are expressed as numbers and percentages. Differences between 2 different transport teams were analyzed using the independent sample *t* test or Mann–Whitney *U* test, and Chi-squared tests or Fisher exact test for continuous and categorical variables, respectively.<sup>[11]</sup> We performed the 1:1 propensity score matching (PSM) using nearest neighbor method (caliper: 0.1)<sup>[12,13]</sup> and the following variables: age, sex, ratio of arterial oxygen partial pressure to fractional inspired oxygen (PF ratio), partial pressure of arterial carbon dioxide (PaCO<sub>2</sub>), systolic blood pressure, heart rate, respiratory rate, pulse oximetry saturation, purpose of transport (diagnostic/therapeutic), and use of inotropes and sedatives. The presence of RRT member and same confounder as PSM analysis were adjusted for multivariate logistic analysis. After performing PSM, continuous and categorical variables were compared using paired *t* test or Wilcoxon signed-rank test as appropriate and McNemar test, respectively. *P* values of <.05 were considered statistically significant. Statistical analyses were performed using SPSS version 23.0 for Windows (SPSS, Chicago, IL and R version 3.3.2 (R Foundation for Statistical Computing, Vienna, Austria).

## 3. Results

During the study period, a total of 642 patients admitted in MICU underwent IHT. About 458 of them met the exclusion criteria, and 184 were finally enrolled. Then 30 patients from each group were selected for the 1:1 PSM (Fig. 1).

Without PSM, no significant difference was found for age, sex, and the number of transports with resident between the general member group and RRT group (age, 73 [IQR: 63–76] vs 72 [IQR: 61–75]; male, 64.2% vs 52.8%; the number of transports with resident, 7.4% vs 14.3%). Respiratory diseases were the most common initial diagnose in both groups. RRT group presented higher APACHE II score ( $32.4 \pm 7.7$  vs  $36.7 \pm 6.0$ ,  $P = .002$ ) and fractional inspired oxygen ( $0.4 \pm 0.2$  vs  $0.5 \pm 0.2$ ,  $P = .004$ ) and PaCO<sub>2</sub> ( $38.5 \pm 10.3$  vs  $45.3 \pm 14.9$ ,  $P = .001$ ) than general member group. Although statistically insignificant, general member groups usually take longer transport turnaround time than the RRT group ( $53.4 \pm 27.9$  vs  $44.4 \pm 21.0$ ,  $P = .073$ ). Sedatives were more frequently used in the RRT group (48.6% vs 77.8%,  $P = .002$ ) (Table 1).

The transport type showed no significant difference between the 2 groups. Computed tomography was the most common purpose of transport followed by peripherally inserted central catheter (PICC) insertion (Table 2). Magnetic resonance imaging was performed only in the general members group because of device issues. Regarding adverse events, cardiopulmonary arrest did not occur during all transports. Hypertension or hypotension was most common, followed by desaturation and accessed line dislodgement. Desaturation events occurred only in the RRT group (Table 3). When comparing according to adverse events

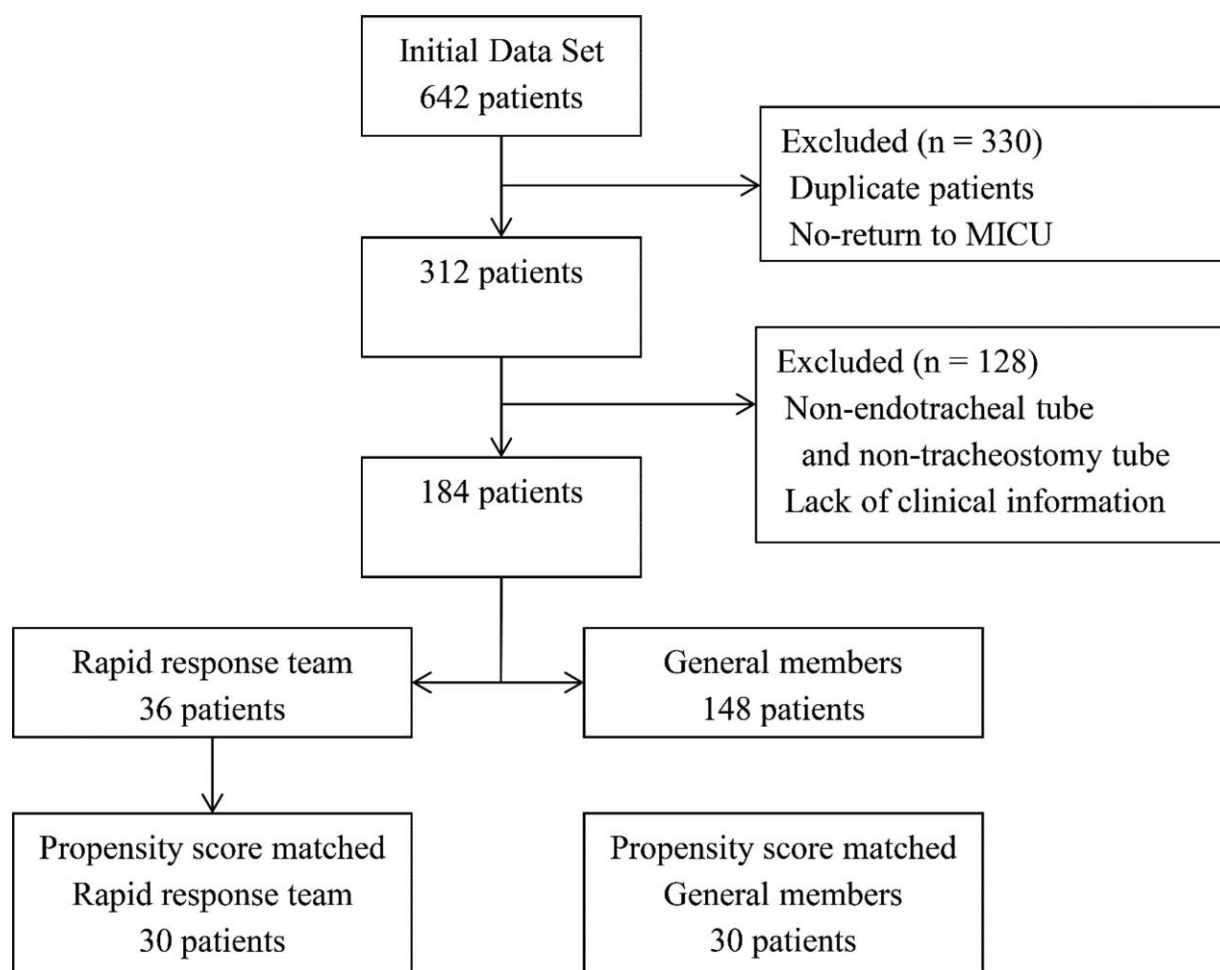


Figure 1. Flow diagram showing patient selection. MICU=medical intensive care unit.

**Table 1**  
General characteristics according to transport team member.

Variables	General members n = 148	RRT* n = 36	P-value
Age, year, median (IQR)	73 (63–76)	72 (61–75)	.456
Male	95 (64.2)	19 (52.8)	.206
Admission diagnoses			
Respiratory	92 (62.2)	29 (80.6)	.049
Cardiovascular	6 (4.1)	2 (5.6)	.692
Sepsis	16 (10.8)	2 (5.6)	.341
Post-resuscitation	25 (16.9)	1 (2.8)	.031
Other	9 (6.1)	2 (5.6)	.905
APACHE II	32.4 ± 7.7	36.7 ± 6.0	.002
Oxygen supply, FIO <sub>2</sub>	0.4 ± 0.2	0.5 ± 0.2	.004
PaO <sub>2</sub> /FIO <sub>2</sub>	275.2 ± 130.3	228 ± 140.5	.057
PaCO <sub>2</sub> , mmHg	38.5 ± 10.3	45.3 ± 14.9	.001
Systolic blood pressure, mmHg	125.9 ± 24.9	124.3 ± 19.5	.719
Heart rate, breath/min	94.7 ± 20.6	99.3 ± 26.3	.265
Respiratory rate, breath/min	22.0 ± 7.9	24.3 ± 5.6	.107
O <sub>2</sub> saturation, percentage	96.7 ± 7.1	95.4 ± 5.3	.351
Transport time, min	53.4 ± 27.9	44.4 ± 21.0	.073
Length of ICU stay, † d	5.9 ± 6.0	8.1 ± 7.8	.134
The use of inotropic agent	88 (59.5)	23 (63.9)	.626
The use of sedative agent	72 (48.6)	28 (77.8)	.002

Values are presented as mean ± SD or number (%).  
APACHE=acute physiology and chronic health evaluation, FIO<sub>2</sub>=fraction of inspired oxygen, ICU=intensive care unit, IQR=interquartile range, PaCO<sub>2</sub>=partial pressure of carbon dioxide in arterial blood, PaO<sub>2</sub>=partial pressure of oxygen in arterial blood, RRT=rapid response team.

\* RRT group includes well-trained nurse in addition to general members.

† Duration of ICU stay before the transport.

**Table 2**  
Types of intrahospital transport and destination.

Variables	Total n = 184	General members n = 148	RRT* n = 36	P-value
Transport type				.613
Diagnostic	104 (56.5)	85 (57.4)	19 (52.8)	
Therapeutic	80 (43.5)	63 (42.6)	17 (47.2)	
Transport purpose				
Computed tomography	72 (39.1)	56 (37.8)	16 (44.4)	.466
MRI	18 (9.8)	18 (12.2)	0 (0)	.026
Fluoroscopy	5 (2.7)	4 (2.7)	1 (2.8)	1.000
PICC	37 (20.1)	33 (22.3)	4 (11.1)	.167
PCD	16 (8.7)	11 (7.4)	5 (13.9)	.218
Embolization	4 (2.2)	3 (2)	1 (2.8)	.585
Percutaneous coronary intervention	6 (3.2)	5 (3.4)	1 (2.8)	1.000
Others <sup>†</sup>	26 (14.2)	18 (12.2)	8 (22.2)	.120

Values are presented as number (%).  
MRI=magnetic resonance imaging, PCD=percutaneous catheter drainage, PICC=peripherally inserted central catheter, RRT=rapid response team.

\* RRT group includes well-trained nurse in addition to general members.

† Endoscopy, ultrasound, bronchoscopy, perm catheter, or Levin tube insertion.

**Table 3**  
Incidence of adverse events during intrahospital transport.

Variables	Total n=184	General members n=148	RRT* n=36	P-value
Cardiopulmonary arrest	0	0	0	N/A
Physiologic derangement				
Hypertension or hypotension	10 (5.4)	8 (5.4)	2 (5.6)	1.000
Desaturation	5 (2.7)	0 (0)	5 (13.9)	.001
Irritability	1 (0.5)	1 (0.7)	0 (0)	1.000
Equipment-related complications				
Dislodgement of endotracheal or tracheostomy tube	1 (0.5)	1 (0.7)	0 (0)	1.000
Dislodgement of central or peripheral line	5 (2.7)	2 (1.4)	3 (8.3)	.052

Values are presented as number (%).

N/A=not applicable, RRT=rapid response team.

\* RRT group includes well-trained nurse in addition to general members.

(Supplemental Content, Table 1, <http://links.lww.com/MD/C668>), among the variables, only prechecked heart rate showed significant difference between the both groups ( $97.4 \pm 21.5$  vs  $82.7 \pm 19.5$ ,  $P=.003$ ). The use of inotropic and sedative agent was relatively more frequent in the adverse events groups, but statistically insignificant (58.0% vs 77.3%,  $P=.083$ ; 51.9% vs 72.7%,  $P=.065$ ; respectively). In multivariate analysis, the odd ratio of RRT group for the presence of adverse event was 6.65 (confidence interval: 1.85–23.89,  $P=.004$ ) (Supplemental Content, Table 2, <http://links.lww.com/MD/C668>).

After PSM, there were no significant differences between the both transport groups in all of general characteristics including APACHE II, fractional inspired oxygen, and PF ratio (Table 4). In

**Table 4**  
Comparison between the rapid response team and general member group.

Variables	Propensity score matched patients		P-value
	General members n=30	RRT* n=30	
Age	70 (62–75)	72 (61–75)	.835
Male	17 (56.7)	16 (53.3)	.795
Respiratory disease <sup>†</sup>	16 (53.3)	23 (76.7)	.058
Oxygen supply, FiO <sub>2</sub>	0.4 ± 0.2	0.5 ± 0.2	.070
PaO <sub>2</sub> /FiO <sub>2</sub>	242.8 ± 106.5	236.6 ± 147.1	.852
PaCO <sub>2</sub> , mm Hg	41 ± 11.7	42.5 ± 11	.604
Systolic blood pressure, mm Hg	123 ± 22.2	125.1 ± 20.6	.697
Heart rate, breath/min	99.4 ± 17	97.8 ± 26.2	.789
Respiratory rate, breath/min	24 ± 5.8	23.7 ± 5.5	.856
O <sub>2</sub> saturation, percentage	96 ± 6.9	95.3 ± 5.7	.670
APACHE II	37.2 ± 6.5	36.0 ± 5.5	.456
Transport time, min	52.4 ± 24.5	45.4 ± 21	.248
Length of ICU stay, <sup>‡</sup> d	6.1 ± 5.9	7.6 ± 7.4	.387
Destination			.432
Therapeutic	19 (63.3)	16 (53.3)	
Diagnostic	11 (36.7)	14 (46.7)	
The use of inotropic agent	19 (63.3)	19 (63.3)	1.000
The use of sedative agent	20 (66.7)	22 (73.3)	.573

Values are presented as mean ± SD or number (%).

APACHE=acute physiology and chronic health evaluation, FiO<sub>2</sub>=fraction of inspired oxygen, ICU=intensive care unit, IQR=interquartile range, PaCO<sub>2</sub>=partial pressure of carbon dioxide in arterial blood, PaO<sub>2</sub>=partial pressure of oxygen in arterial blood, RRT=rapid response team.

\* RRT group includes well-trained nurse in addition to general members.

<sup>†</sup> Admission diagnoses.

<sup>‡</sup> Duration of ICU stay before the transport.

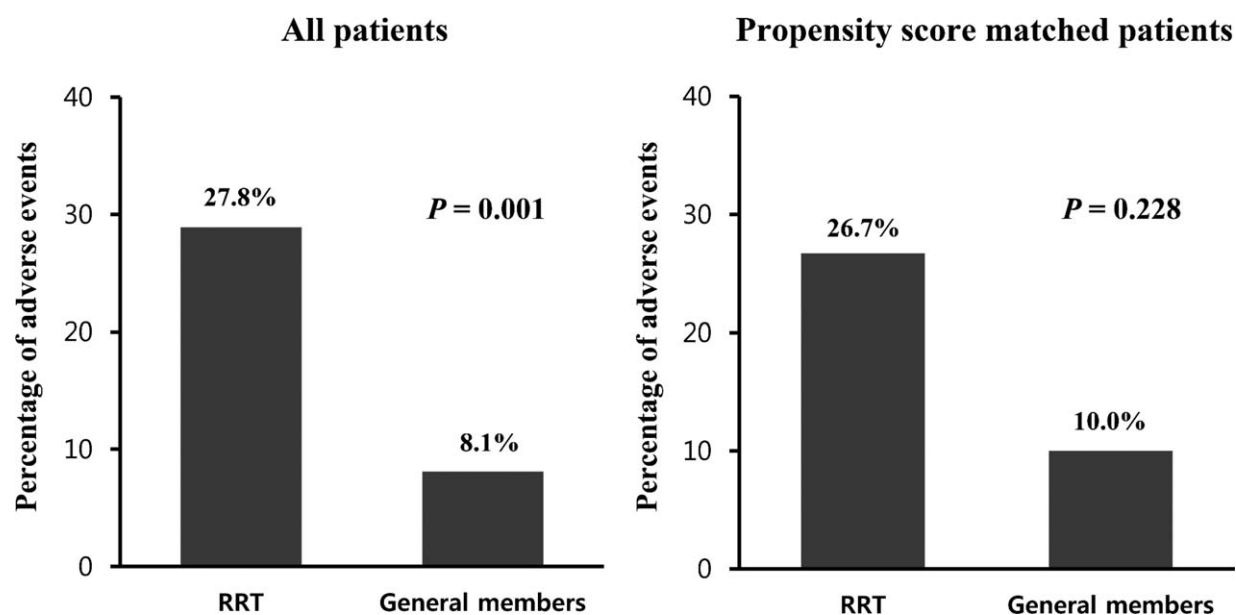
comparison for overall adverse events according to the member of transport team, before PSM, RRT group had significantly higher incidence than general member group (27.8% vs 8.1%,  $P=.001$ ). After PSM, although no statistical significance was observed between both groups, a greater number of overall adverse events were observed in the RRT group (26.7% vs 10.0%,  $P=.228$ ) (Fig. 2).

#### 4. Discussion

In summary, transportation of critically ill patients was associated with higher APACHE II scores, the need for higher oxygen supply, and frequent use of sedatives in the RRT group, which showed no cardiopulmonary arrest, but the incidence of adverse events was higher than that of the general member group. After PSM, although differences in the incidence of adverse events in both groups were statistically insignificant, the incidence of adverse events remained higher during IHT by the RRT.

Unexpectedly, our study data did not show decreasing effect of adverse events even with the participation of RRT member. Especially, desaturation was more frequent in the RRT group and this is probably due to the reason that the intensivist may have been more likely to include patients with an unstable respiratory condition in the RRT group because the RRT members advantage of being able to skillfully handle the portable ventilator. These results suggest that the incidence of adverse events was more related to patient factors, such as severity and demand in various supportive cares, than to the competence of team members. In previous studies, trained personnel and dedicated team reduced unexpected problems.<sup>[6,14–16]</sup> However, another study observed no individual increase in the complication among junior doctors who supported more than 5 transports.<sup>[15]</sup> In the present study, RRT group had higher APACHE II score and needed more demand to support as oxygen supply and sedatives. All these factors could influence more incidences of adverse event in the RRT group. In multivariate regression analysis, RRT group showed more incidences of adverse events, and after PSM, although there was no significant difference, the incidence of adverse events remained higher in the RRT group. These results suggest that other risk factors related to adverse events could be present in addition to the compared factors in this study. In this respect, the reasons for the decision by the intensivist on RRT participation can also be an important risk factor related to adverse events. Further studies considering these factors could provide substantial information for judging the usefulness of RRT participation in IHT. Consequently, in terms of adverse events, the validity of additional medical resources' input to IHT has not been confirmed in the present study.

Nevertheless, participation of experienced member for critically ill patients transport cannot be regarded as efforts to no purpose. The careful monitoring and resolution of a critical event during transport might better reflect competence of the transport team rather than the incidence of events. APACHE II score of RRT group in present study was very high ( $36.7 \pm 6.0$ ) compared to other studies, usually less than mean 20.<sup>[17,17,18]</sup> In transport of these very serious patients, the participation of RRT member could be valuable in that it has completed transport purpose without critical events such as cardiopulmonary arrest. In addition, it is not clear yet that rates of adverse events during transport have definitely correlation with substantive critical ill patient outcome including morbidity and mortality.<sup>[19]</sup> Furthermore, as mentioned above, severely ill patients took a purpose of IHT without critical event, and this fact may offer an attending



**Figure 2.** Comparison of overall adverse events based on the transport team member. Rapid response team (RRT) group includes well-trained nurse in addition to general members.

physician who might be concerned about accidents that may occur during transport a greater chance to select appropriate diagnostic tests or therapeutic procedures, resulting in better clinical outcomes. In future research, in addition to the consideration of practical benefits gained by transport, the incidence of adverse events associated with patient factors and transport preparation policy and occurrence of critical events associated with the competence of the transport team's appropriate response to unexpected situations should be considered separately as 2 different concepts.

Other factors such as the use of portable mechanical ventilator, required transport time, and type of transport have been suggested risk factors relating to adverse events during IHT. However, the results of the associations varied according to the authors.<sup>[5,17,20,21]</sup> The aid of a portable ventilator has shown an advantage in term of less change in physiologic state.<sup>[22]</sup> However, inadequate handling maneuvers about portable mechanical ventilator account for a considerable portion of equipment related adverse events. Damm et al reported that around 22% of IHT involve adverse events relating to portable mechanical ventilators.<sup>[21]</sup> In the present study, although portable ventilator was used for all RRT group transport, adverse events related ventilator such as gas or electrical failure were not observed. The preparation and operating of portable ventilator have been one of the RRT nurse's task so they had already sufficient experience to implement portable ventilator to critically ill patients. This may be a possible benefit from the support of RRT members. Doring et al and Lovell et al reported that that required IHT time associated with incidence of adverse events<sup>[17,20]</sup> and Damm et al showed that adverse events are more frequent in diagnostic testing group.<sup>[21]</sup> On the contrary, other studies stated that transport time and type had no correlation with an increase in adverse events.<sup>[5,23]</sup> The present study data also showed no significant association adverse events with transport time and type.

This study had a few limitations. First, there was no dedicated chart reporting adverse events and reporting adverse events were

relied on only staffed ICU nurses. Accordingly, there could be misses in taking over or reporting by transport member or ICU nurses. To evaluate the quality of IHT more accurately, it is should be considered that participated transport members fill out recording sheet about IHT. Second, the precise reactions performed by RRT nurses for adverse events and the impact of IHT by RRT group on patient's outcome such as mortality or ICU length of stay were not assessed in this study. Third, the sample size was relatively small. This may have underpowered our analysis of the adverse events. One of the reasons is that we wanted to determine the usefulness of RRT in more severe patients thereafter the inclusion criteria was set only for patients who were intubated with respiratory failure.

## 5. Conclusion

During IHT by RRTs in critically ill patients, the addition of a well-trained RRS nurse to general members did not show an additional preventative effect on the incidence of adverse events. To guarantee the validity of RRTs in participating in IHT, future studies that consider the comprehensive various practical factors besides adverse events are required.

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## Author contributions

**Conceptualization:** Won Gun Kwack, Young-Jae Cho.  
**Data curation:** Miae Yun, Dong Seon Lee, Hyunju Min, Yun Young Choi.  
**Formal analysis:** Sung Yoon Lim, Youlim Kim, Sang Hoon Lee, Yeon Joo Lee, Jong Sun Park.  
**Writing – original draft:** Won Gun Kwack.

**Writing – review & editing:** Young-Jae Cho.  
 Won Gun Kwack orcid: 0000-0001-9611-4341.

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