[Original Research]

CHEST

ICU Telemedicine Reduces Interhospital ICU Transfers in the Veterans Health Administration

Spyridon Fortis, MD; Mary V. Sarrazin, PhD; Brice F. Beck, MAE; Ralph J. Panos, MD; and Heather S. Reisinger, PhD

BACKGROUND: The effect of ICU telemedicine on transfers is not well studied. This study tests the hypothesis that ICU telemedicine decreases ICU patient interhospital transfers.

METHODS: Data were retrieved for patients admitted to 306 Veterans Affairs ICUs in 117 acute care facilities between 2011 and 2015. Telemedicine was provided to 52 ICUs in 23 acute care facilities by two support centers located in Minneapolis and Cincinnati. We compared interhospital transfer rates in ICU telemedicine-affiliated hospitals with transfer rates of facilities with no telemedicine program. We used generalized linear mixed multivariable models to assess the association of ICU telemedicine with transfer rates and 30-day mortality.

RESULTS: A total of 553,523 admissions to Veterans Affairs ICUs (97,256 to telemedicine hospitals; 456,267 to non-telemedicine hospitals) were analyzed. Transfers decreased from 3.46% to 1.99% in the telemedicine hospitals and from 2.03% to 1.68% in the non-telemedicine facilities between pre- and post-telemedicine implementation periods ($P <$ .001). After adjusting for demographics, illness severity, admission diagnosis, and facility, ICU telemedicine was associated with overall reduced transfers with a relative risk (RR) of 0.79 (95% CI, 0.71-0.87; $P <$ .001); this reduction occurred in patients with moderate (RR, 0.77; 95% CI, 0.61-0.98; $P =$.034), moderate to high (RR, 0.79; 95% CI, 0.63-0.98; $P =$.035), and high illness severity (RR, 0.73; 95% CI, 0.60-0.90; $P =$.003) and in nonsurgical patients (RR, 0.82; 95% CI, 0.73-0.92; $P =$.001). Transfers decreased in patients admitted with GI (RR, 0.55; 95% CI, 0.41-0.74, $P <$ .001) and respiratory admission diagnoses (RR, 0.52; 95% CI, 0.38-0.71; $P <$ .001). ICU telemedicine was not associated with an increase in 30-day mortality.

CONCLUSIONS: ICU telemedicine was associated with a decrease in interhospital ICU transfers.

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KEY WORDS: ICU telemedicine; interhospital transfers; mortality; tele-ICU

ABBREVIATIONS: APACHE = Acute Physiology and Chronic Health Evaluation; RR = relative risk; TM = telemedicine; VHA = Veterans Health Administration

AFFILIATIONS: From the Center for Comprehensive Access & Delivery Research & Evaluation (CADRE) (Drs Fortis, Sarrazin, and Reisinger; and Mr Beck), Iowa City VA Health Care System, Iowa City, IA; Department of Internal Medicine (Dr Fortis), Division of Pulmonary, Critical Care and Occupation Medicine, University of Iowa Roy J. and Lucille A. Carver College of Medicine, Iowa City, IA; Department of Internal Medicine (Drs Sarrazin and Reisinger), Division of General Internal Medicine, University of Iowa Roy J. and Lucille A. Carver College of Medicine, Iowa City, IA; Pulmonary, Critical Care, and Sleep Division and Cincinnati Tele-ICU (Dr Panos), Cincinnati VAMC, Cincinnati, OH; and the Pulmonary, Critical Care, and Sleep Division (Dr Panos), University of Cincinnati College of Medicine, Cincinnati, OH.

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CORRESPONDENCE TO: Spyridon Fortis, MD, Pulmonary, Critical Care and Occupation Medicine, University of Iowa Hospitals and Clinics, 200 Hawkins Dr – C33 GH, Iowa City, IA 52242; e-mail: spyridon-fortis@uiowa.edu

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ICU telemedicine (TM) is one strategy to provide critical care to hospitals that lack adequate intensivist staffing. The Veterans Health Administration (VHA) has implemented ICU TM in several hospitals, in part, to fill this gap.[1] The effect of TM on ICU mortality is small,[1-4] but ICU TM may potentially reduce transfers from regional hospitals to larger facilities. Although Yeo and colleagues suggest that 25% to 75% of transferred patients could receive proper care locally by intensivists using TM tools,[5] lowering the cost of care and improving patient, family, and staff satisfaction,[6] a study showed that ICU TM increases interhospital transfers from community ICUs to a single tertiary center.[7] That report was limited by the small sample size, close proximity of the community hospitals' ICUs to the reference tertiary center, and the single tertiary center to which all patients were transferred was the ICU TM hub. The effect of ICU TM on interhospital transfers of critically ill patients still remains unclear.

Our study objective was to examine the association of ICU TM with interhospital transfers of ICU patients to other acute care facilities. We use VHA data to compare the proportion of ICU patients in hospitals affiliated with an ICU TM program who transferred to other acute care facilities with the proportion of ICU patients in facilities with no ICU TM program who transferred to other acute care facilities.

Methods

This study is part of an ongoing larger mixed methods analysis of the implementation and outcomes of ICU TM that was approved by the institutional review board at the University of Iowa and Iowa City Veterans Affairs (VA) Health Care System. Both institutional review boards waived the requirement for subject informed consent [45 CFR 46.117(c)]. Prior study analyses have examined ICU TM outcomes, utilization, and acceptance.[1,8,9]

Settings

We extracted inpatient data available from the VHA inpatient datasets through the VHA Austin Automation Center, as well as laboratory and vitals data from the Corporate Data Warehouse and the VA Vital Status File. We retrieved data for all patients admitted to 306 VA ICUs in 117 acute care facilities from October 1, 2009, to September 30, 2015. We excluded patients who did not have any laboratory and vital data required for the illness severity adjustment scale (see the following section) or if demographic or diagnosis category information was missing.

During the study period, the VA implemented ICU TM in 52 ICUs in 23 acute care facilities, located within nine states. ICU TM program implementation took place at various times across these ICUs between 2011 and 2014 (e-Fig 1).

Definitions and Outcomes

Patient age, sex, and race were obtained from the admission record. Race was categorized as white, black, other nonwhite, and missing. Rural residence was defined using the patient's residential ZIP code and Rural Urban Commuting Area codes and categorized as rural or urban. ICU admission type was categorized as medical or surgical, and ICU diagnosis category was defined based upon International Classification of Diseases, 9th Revision, Clinical Modification code. Because not all the components of the Acute Physiology and Chronic Health Evaluation (APACHE) III score were available to calculate APACHE scores, we developed an illness severity adjustment scale using all the APACHE III score predictor variables[10] excluding arterial blood gases, urine output, and Glasgow coma scale. Our illness severity scale has very good discrimination for 30-day mortality (C statistic = 0.77). Severity of illness quartiles were defined on the basis of the illness severity scale.

Interhospital transfer from the ICU to another acute care facility was the primary outcome. We defined interhospital transfer as direct transfer out of the ICU (ie, without transfer to a lower intensity unit) with the discharge disposition indicating transfer to another acute care hospital (VA or non-VA facility). Our secondary outcome was mortality within 30 days of ICU admission defined using dates of death available in the VA Vital Status File.

Statistical Analysis

For patients who were missing some, but not all, values required for the illness severity adjustment scale, imputations were performed using the SAS Enterprise Guide. Imputations were performed only for incomplete vital and laboratory data.

In addition to ICU telemedicine, changes in transfers or mortality after TM implementation may have been affected by transformations in critical care management or modifications in overall VHA care during the study period. For that reason, we not only analyzed outcomes before and after ICU TM implementation, but also compared the magnitude of change in outcomes before and after ICU TM with the magnitude of change in outcomes over the same periods in non-TM ICUs (relative change or relative risk [RR]).

For the bivariate unadjusted analyses, we defined pre-TM and post-TM periods as the time period before and after TM implementation, respectively, based upon the TM implementation date for each ICU. Because one-half of the TM implementations had occurred by March 1, 2012, we defined the pre-TM and post-TM periods for non-TM ICUs as the time periods before and after March 1, 2012, respectively. We used χ^2 to compare transfers or mortality between pre-TM and post-TM periods. To examine whether the change in transfers between pre-TM and post-TM periods in the ICU TM group was different than the change between the pre-TM and post-TM period in the non-TM group, we used logistic regression.

For the adjusted analysis, we used generalized linear mixed multivariable binomial regression models with a log link and random facility intercepts to evaluate the association of ICU TM with transfers while simultaneously adjusting for changes in patient characteristics over time. Time was included in models as a continuous variable. Models were also adjusted for patient age, sex, race, rural residence, illness severity, admission type, admission diagnosis, and facility. For each patient, the model included two variables representing: (1) ICU admission in a hospital that implemented ICU TM at any time during the observation period and (2) ICU admission to an ICU TM hospital after the ICU TM implementation date. The exponentiated value of the first variable provides the RR of transfer in ICU TM hospitals relative to non-ICU TM hospitals at the start of the observation period. The exponentiated value of the second variable provides the RR of transfer in ICU TM hospitals after ICU TM implementation relative to before ICU TM implementation. Similar models were estimated to evaluate the impact of ICU TM implementation on 30-day mortality. These analyses were repeated in patient subsets defined by severity of illness quartiles; admission diagnosis, category, and type; rural residence; hospital transfer rates; and ICU volume. All analyses were conducted using SAS Enterprise Guide, 2014 SAS Institute Inc.

Results

We identified 563,491 ICU admissions, of which 9,963 (1.77%) were excluded for missing data. Characteristics of the remaining 553,523 ICU admissions are shown in Table 1. Two or fewer laboratory values were missing for 198,081 ICU admissions (35.15% of total admissions) and more than two laboratory values were missing for 28,297 admissions (5%). Imputations were performed for missing data. Results of nonimputed and imputed analyses were similar (e-Table 1). Overall, interhospital transfers decreased by 1.47% (from 3.46% to 1.99%) after TM implementation in ICU TM hospitals compared with 0.34% in the non-TM hospitals ($P < .001$) (Table 2). In unadjusted analysis, TM was associated with a transfer decline in all severity of illness quartiles except the lowest acuity quartile, in patients admitted with GI and respiratory diagnoses, and in nonsurgical patients. We observed similar results regardless of the admission day (weekday vs weekend day) (e-Table 2).

Transfers decreased by 0.98% (from 2.9% to 2.58%) in ICUs covered by the Cincinnati support center and by 2.65% (from 6.26% to 3.94%) in ICUs covered by the Minneapolis support center.

In adjusted analysis, the overall RR of ICU transfers among ICU telemedicine facilities was reduced to 0.79 (95% CI, 0.71-0.87; $P < .001$) (Fig 1). ICU TM was associated with a reduction in transfers in all illness severity quartiles except the lowest acuity quartile in patients with GI (RR, 0.55; 95% CI, 0.41-0.74; $P < .001$) and respiratory admission diagnoses (RR, 0.52; 95% CI, 0.38-0.71; $P < .001$). TM was associated with a transfer

TABLE 1] Patient Characteristics

Characteristic	ICU TM		Non-TM	
	Pre-TM	Post-TM	Pre-TM	Post-TM
ICU admissions, No.	62,143	35,113	192,654	263,613
Age, mean (SE), y	64.45 (0.05)	65.92 (0.06)	65.74 (0.03)	66.36 (0.02)
Women, No. (%)	2,455 (3.95)	1,152 (3.28)	6,743 (3.5)	10,061 (3.82)
Race, No. (%)				
White	42,748 (68.79)	27,362 (77.93)	144,160 (74.83)	197,119 (74.78)
Black	15,900 (25.59)	5,786 (16.48)	32,386 (16.81)	47,127 (17.88)
Other	2,630 (4.23)	1,379 (3.93)	11,544 (5.99)	15,509 (5.88)
Missing	865 (1.39)	586 (1.67)	4,564 (2.37)	3,858 (1.46)
Rural patients, No. (%)	10,052 (16.18)	6,697 (19.07)	26,756 (13.89)	34,659 (13.15)
Diagnosis, No. (%)				
Cardiovascular	20,144 (32.42)	11,039 (31.44)	63,544 (32.98)	84,330 (31.99)
Endocrine	2,239 (3.6)	1,095 (3.12)	5,235 (2.72)	7,325 (2.78)
GI	8,323 (13.39)	4,523 (12.88)	26,965 (14)	35,402 (13.43)
Genitourinary	4,092 (6.58)	2,203 (6.27)	12796 (6.64)	16561 (6.28)
Heme/onc	2,150 (3.46)	1,173 (3.34)	7,111 (3.69)	8,952 (3.4)
Neurological	4,138 (6.66)	2,344 (6.68)	11,954 (6.2)	16,992 (6.45)
Other	9,284 (14.94)	5,265 (14.99)	30,850 (16.01)	41,348 (15.69)
Respiratory	8,890 (14.31)	5,251 (14.95)	28,465 (14.78)	38,280 (14.52)
Sepsis	2,883 (4.64)	2,220 (6.32)	5,734 (2.98)	14,423 (5.47)
Surgery, No. (%)	17,741 (28.55)	11,160 (31.78)	66,418 (34.48)	88,463 (33.56)
LOS, mean (SE), d	8.07 (0.05)	7.62 (0.05)	9.49 (0.04)	8.73 (0.02)
30-d mortality, No. (%)	4,270 (6.87)	2,429 (6.92)	15,187 (7.88)	19,805 (7.51)
Transfers	2,148 (3.46)	699 (1.99)	3,903 (2.03)	4,440 (1.68)

Heme/onc = hematological-oncological; LOS = length of stay; TM telemedicine.

TABLE 2] Interhospital ICU Transfers by Admission Diagnosis Category, Admission Type, and Rurality

Category	ICU TM					Non-TM					P^{a}
	Pre-TM		Post-TM			Pre-TM		Post-TM			
	Tx	Adms	Tx	Adms	ARR (95% CI)	Tx	Adms	Tx	Adms	ARR (95% CI)	
All	2,148	62,143	699	35,113	1.47% (1.26-1.67)	3,903	192,654	4,440	263,613	0.34% (0.26-0.42)	< .001
Illness severity quartile											
1	420	14,970	160	9,424	1.11% (0.73-1.15)	919	48,799	1,039	66,325	0.32% (0.17-0.47)	.17
2	499	15,411	153	8,926	1.52% (1.13-1.91)	978	48,048	1,089	66,430	0.40% (0.24-0.56)	.011
3	542	15,803	188	8,722	1.27% (0.86-1.69)	999	47,836	1,110	65,824	0.40% (0.24-0.56)	.026
4	687	15,958	198	8,041	1.85% (1.39-2.31)	1,007	47,990	1,202	65,060	0.25% (0.08-0.41)	.001
Diagnosis											
CVS	941	20,144	339	11,039	1.6% (1.17-2.03)	2,116	63,544	2,421	84,330	0.46% (0.28-0.64)	.38
Endocrine	20	2,239	5	1,095	0.44% (−0.12 to 0.99)	39	5,235	27	7,325	0.38% (0.11-0.65)	.73
GI	306	8,323	77	4,523	1.97% (1.42-2.53)	393	26,965	436	35,402	0.23% (0.04-0.41)	< .001
GU	85	4,092	32	2,203	0.62% (−0.04 to 1.29)	110	12,796	131	16,561	0.07% (−0.14 to 0.28)	.82
Heme/Onc	56	2,150	23	1,173	0.64% (−0.4 to 1.68)	96	7,111	111	8,952	0.11% (−0.24 to 0.46)	.65
Neurological	101	4,138	39	2,344	0.78% (0.08-1.48)	237	11,954	228	16,992	0.64% (0.34-0.94)	.65
Other	202	9,284	77	5,265	0.71% (0.27-1.15)	411	30,850	433	41,348	0.29% (0.12-0.45)	.20
Respiratory	319	8,890	61	5,251	2.43% (1.94-2.91)	399	28,465	472	38,280	0.17% (−0.01 to 0.34)	< .001
Sepsis	118	2,883	46	2,220	2.02% (1.09-2.96)	102	5,734	181	14,423	0.52% (0.14-0.91)	.13
Surgical											
Yes	196	17,741	84	11,160	0.35% (0.13-0.57)	486	66,418	535	88,463	0.13% (0.04-0.21)	.091
No	1,952	44,402	615	23,953	1.83% (1.55-2.11)	3,417	126,236	3,905	175,150	0.48% (0.36-0.59)	< .001
Residence											
Rural	490	10,052	175	6,697	2.26% (1.69-2.83)	747	26,756	813	34,659	0.45% (0.19-0.7)	.009
Urban	1,658	52,091	524	28,416	1.34% (1.12-1.56)	3,156	165,898	3,627	228,954	0.32% (0.23-0.4)	< .001

Adms = patients admitted to ICU; ARR = absolute risk reduction; CVS = cardiovascular; GU = genitourinary; Heme/Onc = hematological-oncological; Tx = transferred patients. See Table 1 legend for expansion of other abbreviations.
[a]Comparison between ICU TM and non-TM.

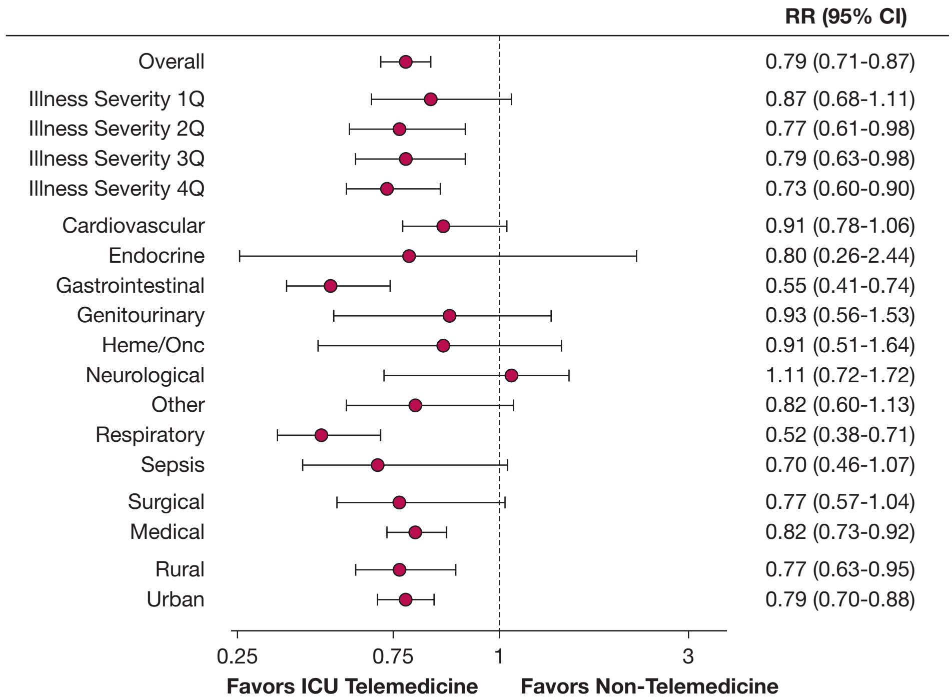

Figure 1 – *Adjusted RR for interhospital transfers showing the RR in interhospital transfers between pre-TM and post-TM periods for ICU TM vs non-TM facilities. All models were adjusted for patient demographics, illness severity, facility, category diagnosis, surgery or medical diagnosis, and residence (rural or urban). Q, quarter; RR = relative risk.*

decrease in medical (RR, 0.82; 95% CI, 0.73-0.92; $P = .001$) but not in surgical patients (RR, 0.77; 95% CI, 0.57-1.04; $P = .087$). We observed similar results between facilities with high and low ICU volume and between facilities with high and low ICU interhospital transfer rates (e-Table 3).

The 30-day unadjusted mortality did not change before (6.87%) and after ICU TM (6.92%; $P = 0.78$). The 30-day unadjusted mortality of transferred patients was 6% and 8.7% ($P = .001$), whereas the mortality in nontransferred patients was 6.9% and 6.9% ($P = .9$) before and after ICU telemedicine, respectively (Fig 2).

In non-TM hospitals, the mortality decreased from 7.88% to 7.51% ($P < .001$) between pre-TM and post-TM periods. The 30-day unadjusted mortality of transferred patients was 5.8% and 6.3% ($P = .34$) and

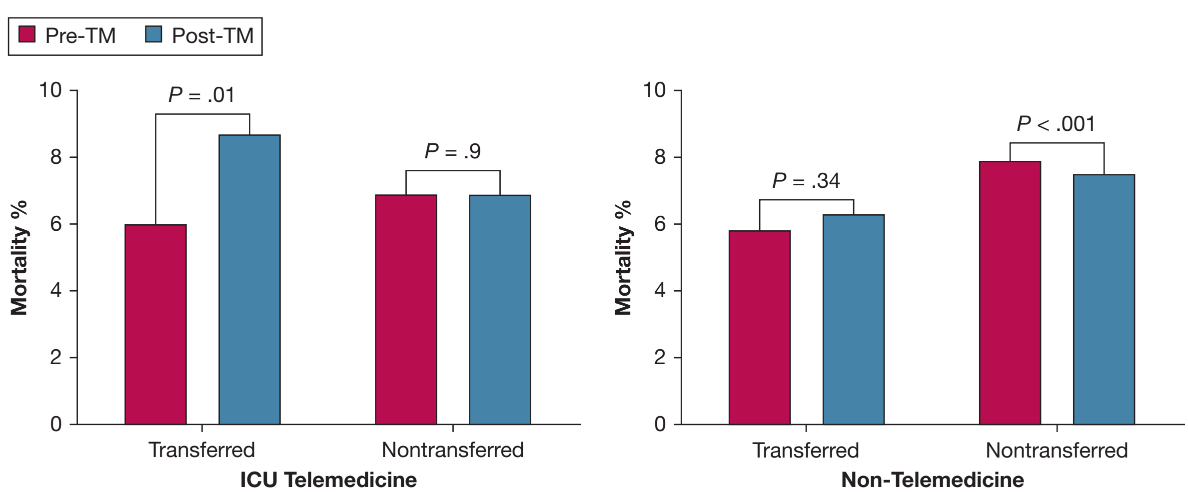

Figure 2 – *Thirty-day unadjusted mortality in transferred and nontransferred patients in the ICU TM and non-TM ICUs. The comparison between pre-TM and post-TM periods was performed using χ^2 analysis. TM = telemedicine. See Figure 1 legend for expansion of other abbreviations.*

the mortality in nontransferred patients was 7.9% and 7.5% ($P < .001$) in the pre-TM and post-TM periods, respectively.

In the adjusted analysis, ICU telemedicine did not affect 30-day mortality (e-Table 4); however, mortality decreased over time in the non-TM group. The relative risk for 30-day mortality in the TM ICUs compared with the non-TM ICUs was 1.08 (95% CI, 1.01-1.14; $P = .01$) (Fig 3). The relative risks for 30-day mortality in TM ICUs compared with non-TM ICUs were increased in the third illness severity quartile (RR, 1.23; 95% CI, 1.05-1.43; $P = .01$), in patients with hematological-oncological diagnoses (RR, 1.33; 95% CI, 1.03-1.71; $P = .03$), and in transferred patients (RR, 1.67; 95% CI, 1.16-2.40; $P = .005$).

Discussion

Overall, ICU TM was associated with a decrease in interhospital ICU transfers after adjusting for demographics, illness severity, admission diagnosis, and facility. The association of ICU TM with reduced interhospital transfers was present in patients with moderate and high illness severity, in nonsurgical patients, and patients admitted with gastrointestinal and respiratory diagnoses. ICU TM did not change overall adjusted or unadjusted 30-day mortality.

Interhospital ICU transfers decreased from 3.46% to 1.99% (a relative change of 42.49%) after ICU TM implementation. In another study, administrators and clinicians in rural hospitals estimated that transfers were reduced by 37% after ICU TM implementation[6]; however, a study conducted in a single regional health care system showed that transfers increased after ICU TM implementation, whereas the APACHE III score of the transferred patients remained the same.[7] Although we have no details of their ICU TM program, the increase in transfers is likely related to the fact that TM support was provided by the referral tertiary program, which was also located 42 to 127 miles from the community hospital ICUs.[7] The constancy of transferred patients' APACHE III scores before and after TM implementation suggests that this particular TM program may operate primarily to transfer patients to the tertiary center.[7] If ICU TM helped to triage the patients appropriately (keep the patients with low acuity and transfer the sickest patients to other facilities), one would expect that, after telemedicine implementation, the APACHE III score of the transferred patients would increase as the sickest patients would be transferred. For those reasons, we surmise that ICU TM staff encouraged patient transfers from local community hospitals to the tertiary hospital.

In our study, the effect of ICU TM on transfers was present in all patients except those with mild illness

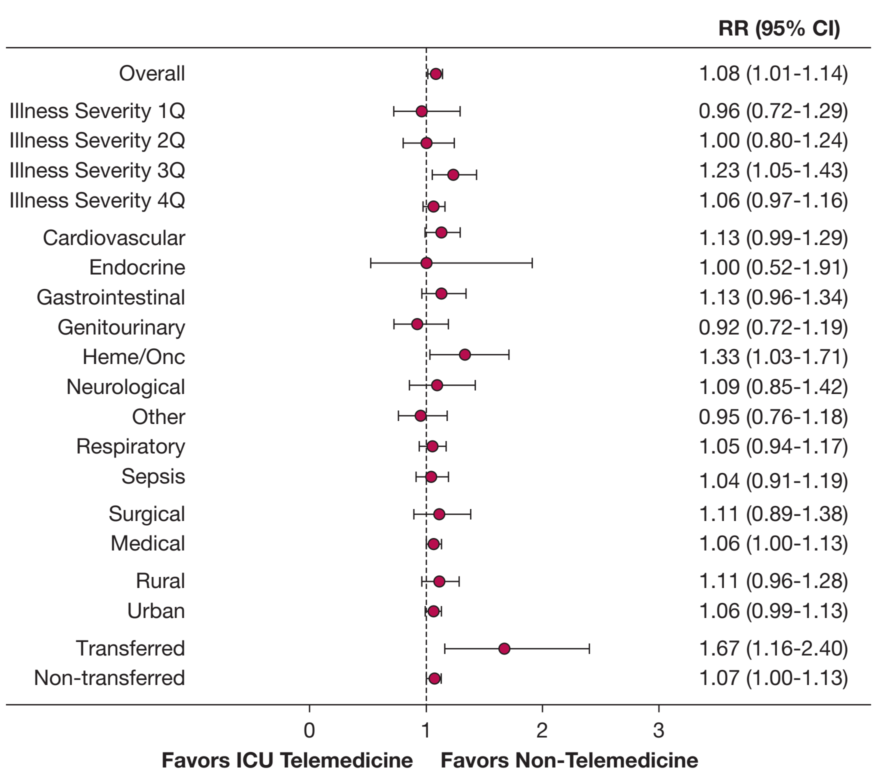

Figure 3 – *Relative risk for 30-day adjusted mortality and post-TM periods for ICU TM vs non-TM facilities. All models adjusted for patient demographics, illness severity, facility, category diagnosis, surgery or medical diagnosis, and rurality. See Figure 1 and 2 legends for expansion of other abbreviations.*

severity. Staff in low-acuity ICUs may feel uncomfortable or unable to care for very sick patients.TM, by providing critical care expertise locally, may prevent the transfer of these patients to other facilities.

The transfer decline occurred mainly in patients with respiratory and GI admission diagnoses. Although it is unclear why transfers decreased in patients with GI admission diagnoses, transfer reduction in respiratory patients may occur because of remote availability of critical care expertise through TM. Care of patients with respiratory diseases, in particular those requiring mechanical ventilation, can be challenging; transferring patients requiring mechanical ventilation is common.[11] Once intubation is performed, a tele-intensivist, in collaboration with the bedside respiratory therapist, can comanage these patients remotely by using cameras to watch the patients and review the vital signs and mechanical ventilator settings and wave forms. Thus, transfer of patients with respiratory failure may be avoided.

Transfer decline is unlikely to be related with ICU care improvement in the TM group because the mortality did not change (e-Table 4). ICU TM was not associated with a mortality benefit in our study. Although this finding is in agreement with previous reports,[1,4,12] the majority of the literature demonstrates that ICU TM is associated with a mortality benefit.[2,13,14] The effect of ICU TM on ICU mortality is heterogeneous, and large academic hospitals experience the greatest mortality reductions.[15] The heterogeneity is high in multifacility programs such as our study.[16] In large academic centers, the heterogeneity may be lower with better outcomes because ICU TM may serve a single health care system and be organized around a fewer number of ICUs.[2,16,17]

In the current study, we did not focus on mortality; nevertheless, we did study the effect of transfer reduction on overall mortality. ICU TM was associated with an increase in adjusted 30-day mortality of transferred patients. Although this increase suggests that the patients were triaged appropriately with transfer of the sickest patients, unfavorable outcomes resulting from treatment delays during patient transfers cannot be excluded.[18,19] Overall 30-day mortality was unchanged before and after TM implementation in the TM ICUs, whereas mortality declined during the pre- to postimplementation periods in the non-TM units. The unadjusted mortality in ICU TM-associated facilities, however, was lower than in nonaffiliated hospitals during both the pre- (6.87% vs 7.88%; $P < .001$) and postimplementation periods (6.92 vs 7.51%; $P < .001$). Across diagnostic categories, a relative change in adjusted 30-day mortality occurred in hematological-oncological patients only (e-Table 4). This improved outcome seems unrelated to the transfer reductions because hematological-oncological patients did not experience any decrease in transfers (Table 2).

Although this investigation studied a national health care system with a large number of ICU patients, there are some limitations. Our study population was limited to patients admitted to an ICU. We did not include critically ill patients transferred before ICU admission. Some patients may have been transferred directly to another hospital from the ED and not been admitted to the ICU, whereas trauma and surgical patients may be diverted to other hospitals without even visiting the ED. Conversely, by including all ICU patients, we also studied ICU patients whose care may not have been affected by ICU TM, such as those who required a procedure unavailable at the originating facility. Our ability to perform these stratified analyses was limited by the available data. We do not have detailed information on diverted patients, the bedside staffing levels in the various VHA facility ICUs, or the level of care in the hospitals that received transferred patients. The TM intervention was not blinded and randomized, limitations that were present in previous studies as well.[1,2,14,20] The TM and non-TM ICUs were not matched. For that reason, we repeated the analysis in facilities with low or high ICU transfer rates and ICUs with low or high volume. These analyses revealed similar results. Moreover, we adjusted for facility in our multivariable models. Another potential weakness might be the lack of a specified transfer protocol and that decisions about transferring patients were not standardized. Those limitations do not undermine our study strengths including the large sample size and the availability of a control sample.

In conclusion, ICU TM in VHA was associated with a decrease in interhospital transfers that occurred mainly in patients with more severe illness and those admitted with GI and respiratory diagnoses, and it was not associated with a mortality benefit. ICU TM may have helped to triage and not transfer patients that could be appropriately treated in local ICUs by providing remote access to critical care expertise.

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