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LETTER

Deciphering factors that influence the value of tele-ICU programs

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Dear Editor,

The underlying drivers for ICU telemedicine solutions have primarily been the critical care resource supply/demand mismatch: an aging population with increased ICU utilization and geographic concentration of intensivists in large urban areas, creating access issues elsewhere. A recent systematic review and meta-analysis described significant positive effects of tele-ICU implementation on ICU mortality and length of stay (LOS), which less consistently also translate into reductions of hospital mortality and LOS, as a variety of non-ICU-driven factors influence those metrics (see Table) [1]. Our own recent meta-analysis adds that, while overall ICU mortality reductions can be expected through tele-ICU implementation, the largest ICU mortality improvements can be expected in ICUs with high pre-implementation standardized ICU mortality ratios (observed over expected by risk prediction) [2].

We have also learned that how tele-ICU implementations are planned and executed critically determines their potential for success and value. The elements essential for maximizing tele-ICU value include: (1) careful planning and obtainment of pre-implementation support from all stakeholders (i.e., administration, physician and nurse leadership, ancillary services), (2) close integration of teams and collaborative individualized approaches, and (3) continuous monitoring models with interfaced vital signs and laboratory value monitoring and algorithmic computer-based alert mechanisms (as opposed to episodic on demand consultations) [3]. In an attempt to differentiate which meta-factors influence the success of tele-ICU implementations the most, a recent ethnographic study found that modifiable domains surrounding leadership, perceived value of tele-ICU, change management strategies, and organizational structure are most closely associated with the success of tele-ICU implementation [4].

The most comprehensive and robust experiential financial outcomes study to date demonstrated increased total annual direct ICU contribution margins from US$7921,584 to $37,668,512, decreased average hospital LOS from 10.4 to 9.7 days, and increased annual case volume from 4752 to 5735 [5]. Adding Logistics Center functions geared to increase access to critical care, optimize capacity/throughput and standardize care may promote additional benefits in a tele-ICU service. The above study demonstrated an increase in contribution margin to $60,586,397, a reduction in hospital LOS from 9.7 to 8.8 days, and an increase in the annual case volume from 5735 to 6581). [5] This illustrates the immense potential of such functions for increasing access to critical care and optimizing capacity, particularly in large structurally and/or geographically diverse healthcare systems/organizations using tele-ICUs.

Table 1 summarizes selected recent evidence-based publications illustrating the value potential of tele-ICU programs.

It illustrates that future research should focus on two main directions: (1) confirming the findings regarding outcomes improvement using standardized mortality ratios of patient level data and (2) further clarification of which elements of the multifactorial tele-ICU intervention contribute most. The value for several additional components of tele-ICU interventions like tele-pharmacology support or procedural supervision support are less well defined and deserve further exploration to better define their use case and value potential.

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Table 1 Select recent publications on the value potential of tele-ICU programs, sorted by value and care domains; studies were identified through a conventional literature search and summarize some of the current evidence

	Studies providing data on outcomes and costs											
	Reference	Value domain	Care domain	Study type	Study setting and sample size	Primary outcome/intervention	Results				Costs	Additional data
							ICU mortality	Hospital mortality	ICU LOS	Hospital LOS		
1	Arch Intern Med 2011;171(6):498–506	Improved clinical Outcomes	Tele-ICU	Systematic review and metaanalysis	13 studies	ICU and hospital mortality and LOS	Pooled OR 0.8 (CI 0.66–0.97, $p = 0.02$)	Pooled OR 0.82 (CI 0.65–1.03, $p = 0.08$)	Mean reduction −1.26 days (CI −2.21 to −0.30, $p = 0.01$)	Mean reduction −0.64 days (CI −1.52 to 0.25, $p = 0.16$)	ND	
2	Crit Care 2012;16(4):R127	Improved clinical outcomes	tele-ICU	Systematic review and metaanalysis	11 studies	ICU and hospital mortality and LOS	Risk ratio 0.79 (CI 0.65–0.96)	Risk ratio 0.83 (CI 0.73–0.94)	Reduction of 0.62 days (CI −1.21 to −0.04 days)	Reduction of 1.26 days (CI −2.49 to −0.03 days)	ND	
3	J Intensive Care Medicine 2018; 33(7):383–393	Improved clinical Outcomes	Tele-ICU	Systematic review and metaanalysis	19 studies	ICU and hospital mortality and LOS	Risk ratio 0.83 (CI 0.72–0.96)	Risk ratio 0.74 (CI 0.58–0.96)	Reduction of 0.63 days (CI −1.09 to −0.17 days)	Reduction of 0.27 days (CI −1.14 to 0.59 days)	ND	
4	Fusaro et al; Crit Care Med, https://doi.org/10.1097/ccm.0000000000003627 (2019)	Improved clinical Outcomes	tele-ICU	Systematic review and metaanalysis	13 studies	ICU mortality	Overall reduction (pooled OR 0.75 (0.65–0.87 95% CI, $p < 0.001$)	ND	ND	ND	ND	Greater reduction in ICU mortality if preimplementation observed-over-predicted mortality was high: pooled OR 0.64 (0.52–0.77 95% CI, $p < 0.00001$)
5	Crit Care Med 2018;46(5):728–735	Improved clinical outcomes	Progressive care unit (PCU)	Retrospective observational study	Single large healthcare system in Florida, USA; 16,091 patients	Hospital mortality	ND	Hazard ratio for hospital mortality in telemedicine supported PCU vs. non-telemedicine supported PCU 0.80 (CI 0.67–0.96)	ND	Mean LOS in telemedicine supported PCU 2.6 days (95% CI 2.5–2.7 days) vs. 3.2 days (95% CI 3.1–3.3 days) in non-telemedicine supported PCU ($p < 0.0001$)	ND	

Table 1 (continued)

	Studies providing data on outcomes and costs											
	Reference	Value domain	Care domain	Study type	Study setting and sample size	Primary outcome/intervention	Results				Costs	Additional data
							ICU mortality	Hospital mortality	ICU LOS	Hospital LOS		
6	Crit Care Med 2016; 44(2):265–74	Cost	Tele-ICU	Simulation analysis performed by standard decision models	Hypothetical ICU defined by the US literature	Intervention: introduction of telemedicine in the ICU	ND	ND	ND	ND	ICER of $45,320 per additional QALY	Probabilistic cost-effectiveness analysis estimated an ICER of $50,265
7	Telemed J E Health 2018;24(1):21–36	Cost	Tele-ICU	Simulation analysis	Hypothetical ICU patient cohort	Intervention: Introduction of telemedicine in the ICU	ND	ND	ND	ND	Optimal cost-effectiveness in 30%–40% highest risk ICU patients	
8	Chest 2017;151(2):286–297	Cost	Logistics center	Case cohort study	Single academic medical center; 51,203 patients	Change in annual direct contribution margin with Tele-ICU implementation	ND	ND	ND	Reduction from 10.4 to 9.7 days	Total annual direct contribution margin increased from $7921,584 to $37,668,512	Case volume increased from 4752 to 5735/years
						With addition of logistics center functions	ND	ND	ND	Reduction from 9.7 to 8.8 days	Total annual direct contribution margin further increased to $60,586,397	Case volume further increased to 6581/years

Table 1 (continued)

	Studies providing data on outcomes and costs											
	Reference	Value domain	Care domain	Study type	Study setting and sample size	Primary outcome/intervention	Results				Costs	Additional data
							ICU mortality	Hospital mortality	ICU LOS	Hospital LOS		
9	Chest 2018;154(1):69–76	Cost	Interhospital transfers	Retrospective study	306 veterans affairs ICUs in 117 acute care facilities; 553,523 ICU admissions between 2011 and 2015	Interhospital transfer rates	ND	ND	ND	ND	ND	Transfers decreased from 3.46 to 1.99% in telemedicine hospitals and from 2.03 to 1.68% in non-telemedicine facilities ($p < 0.001$). Adjusted relative transfer risk for telemedicine supported ICUs vs non-telemedicine supported ICUs 0.77 (95% CI 0.61–0.98).

	Hypothesis generating studies						
	Reference	Value domain	Care domain	Study type	Study setting and sample size	Primary outcomes/study aim	Author conclusions
10	Cardiol Rev 2017;25(3):97–101	Increased access and quality	Procedural supervision	Case series	Single large healthcare system in New York	Feasibility study	Tele-ICU supervised tele-ultrasound can effectively guide acute patient mangement.
11	Telemed J E Health 2017;23(4):290–297	Increased access and quality	Intubation support	Prospective observational study	Single large healthcare system in nortwest US; 206 intubation events	Feasibility and success rates	Telemedicine supported endotracheal intubation performed in rural hospitals is feasible with good success rates

Table 1 (continued)

	Hypothesis generating studies						
	Reference	**Value domain**	**Care domain**	**Study type**	**Study setting and sample size**	**Primary outcomes/ study aim**	**Author conclusions**
12	J Telemed Telecare 2018; Sep 25:1357633X18799796	Increased access and quality	Pharmacy	Prospective observational study	Large university hospital in Germany	Number and type of drug related problems (DRPs)	Telepharmaceutical support as addition to tele-ICU services can increase quality of care
13	Am J Disaster Med 2014;9(1):25–37	Increased access and quality	Disaster	Traditional narrative review	N/a	N/a	Telemedicine has potential for disaster management
14	Telemed J E Health 2016;22(12):1024–1031	Increased Access and quality	Tele-ICU	Retrospective descriptive study	Telemedicine network in Albania; 1065 teleconsultations	Feasibility study	Telemedicine can increase access to specialized ICU care in resource poor countries/areas
15	Acad Med 2017; 92(7):1035–1042	Care standardization	Handoffs	Prospective observational study	Large university hospital in Pennsylvania, USA; comparison of 16 daytime and 16 nighttime and weekend OR-to-ICU handoffs supervised through tele-ICU	Quality of OR-to-ICU handoff	Tele-ICU can effectively standardize and monitor operating room to ICU handoffs

All studies included in metaanalyses were before-after studies. The odds ratio, for example, of ICU mortality, relates to the observed over expected ICU mortality ratio after tele-ICU implementation divided by the observed over expected ICU mortality ratio before tele-ICU implementation

LOS length of stay, *OR* odds ratio, *CI* confidence interval, *PCU* progressive care unit, *QALY* quality adjusted life year, *ICER* incremental cost-effectiveness ratio

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