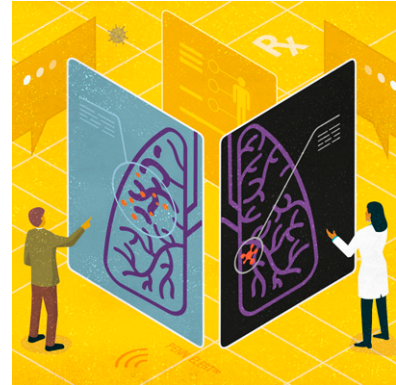


## IN DEPTH

# Deployment of Tele-ICU Respiratory Therapy and the Creation of an eRT Service Line



Krzysztof Laudanski, MD, PhD, MA, FCCM, MHC, Michael Scott, MBChB, FRCP, FRCA, FFICM, Ann Marie Hufferberger, DBA, RN, NEA-BC, Justin Wain, C. William Hanson III, MD

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Penn Medicine launched a 24-7 telemedicine respiratory therapist (eRT) service as part of its tele-critical care medicine (tele-CCM) service serving seven hospitals and more than 320 critical care beds. Service line interventions were focused on protocolized evidence-based practices, safety, documentation compliance, and urgent emergent ad hoc clinical needs. Concomitantly, the eRTs were available to respond to urgent and emergent interventions on the basis of the clinical bedside situation. Their activity was triggered by Penn E-lert staff (serving the tele-ICUs), bedside staff, algorithmic trigger software, or the eRT's own review of a patient's clinical condition. A standardized data collection was deployed to gather information about the interventions. The value of the eRT service was defined in terms of estimated lives saved by implementing the standards of care earlier than the bedside staff would or acute respiratory distress syndrome (ARDS) algorithmic trigger and by intervening during emergent and urgent clinical request, improving care delivery, and complying with best clinical practices, and by the time freed for onsite staff to perform other duties. Between May 2020 and August 2021, eRTs registered 31,609 activities; 97.8% of interventions were related to the routine established workflows, while 1.9% were urgent and 0.3% emergent. In 51.2% of all eRT accomplished activities, no communication with other staff was needed. When communication did take place, eRTs connected with the bedside respiratory therapist in 36.7% of interactions, followed by house staff (7.2%), advanced practice providers (5.2%),

and registered nurses (1.6%). The eRTs communicated via phone (81.4%), asynchronous text platform (16%), or tele-CCM software (1.4%). While prompted by staffing, safety, and logistics challenges during a Covid-19 surge, the resulting eRT service line has been well received and has become a part of the standard of care. Overall efficiency of respiratory care service delivery was increased as Penn retained staff and increased the flexibility of bedside therapists. Furthermore, the eRT service detected unfavorable practice patterns in ARDS treatment and intervened before the ARDS algorithmic trigger was activated or acted upon. Some of the tasks can be accomplished by the eRT in a shorter amount of time than it would take bedside staff. In addition, the remote staffing reduced personal protective equipment utilization. All of these gains translated into postpandemic time savings. Penn's experience shows that the eRT care model can be transformed into a system-valued proposition and retained with sustained benefit beyond the pandemic surge.

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The emergence of Covid-19 created a surge in demand for health care providers and their expertise.<sup>1-3</sup> As a result, several novel ways to deliver health care to patients in various conditions were introduced.<sup>4,5</sup> Some services, previously reserved for bedside only, were outsourced by organizations or reassigned to virtual or remote providers.<sup>1,3,5,6</sup> However, it may be difficult to adapt the many innovative approaches derived during the acute phase of the Covid-19 pandemic from March to May 2020 to more regular settings.<sup>3,6-8</sup> The abatement of the pandemic urgency changed the forces governing the innovation implementation.<sup>3,5,8</sup> For example, personal protective equipment (PPE) supply improved concomitantly with increasing knowledge of how to safely treat patients with Covid-19.<sup>9</sup> Health care stakeholders started analyzing innovation through the lens of sustainability as hospitals recovered toward more standard operations and long-term financial prudence was taken into account.<sup>8</sup> At the same time, significant staff attrition occurred, and already-present burnout among professionals worsened.<sup>10-12</sup> The initiation of a sustainable health care delivery model, created in response to catastrophic events, is understudied within medicine.<sup>3,6,8,13-15</sup> However, understanding these forces is critical for transforming pandemic-catalyzed innovations into generalizable value-based solutions.<sup>6,8,12,13,16</sup>

Respiratory therapists (RTs) manage several aspects of pulmonary care under a physician's supervision.<sup>17-21</sup> However, even before the Covid-19 pandemic, a limited supply of RTs created a significant mismatch between the patients' needs and the available RT services.<sup>3,11,22</sup> A common symptom of the Covid-19 virus is respiratory distress, necessitating the commitment of significant resources, an intense allocation of staff, and the enforcement of quarantine.<sup>23</sup> These characteristics may disproportionately burden RTs as compared with other providers.<sup>10,17,21,24</sup> In March 2020, predicting that respiratory services would be under duress, we devised and implemented a program early in the pandemic, allowing RTs to serve as remote specialists within the existing tele-critical care infrastructure. While there was research on telemedicine extending the availability of critical care specialty physicians and other specialists, there was limited investigation into ensuring the sustainability of innovation regarding remote telemedicine RT (eRT) with the application of tele-technology.<sup>12,14,25,26</sup>

The idea was to reassign some RT staff to Penn E-lert to conduct some of the tasks traditionally assigned to bedside RTs. The staff assigned to Penn E-lert were deemed to be at high risk while taking care of patients with Covid-19 because of their underlying health conditions. The primary goal was to deliver adequate and timely respiratory care using telemedicine while preserving RT staff who otherwise would have to be sidelined.<sup>14,26</sup> The second goal was to see if internal service reallocation of resources also provided higher staff flexibility serving as a workforce multiplier. The eRTs could perform tasks usually assigned to bedside staff — such as ventilator checks or assessment of compliance with low tidal volume ventilation — while bedside RTs could attend to other patients or conduct interventions requiring physical presence (intubation, suctioning, and chest physiotherapy).<sup>20</sup>

In addition, transferring the service mitigates the need for a bedside RT to enter the room, thus reducing the infectious risk to health care workers and reducing staff-to-patient transmission.<sup>1,2,27</sup> Acquisition of Covid-19 by health care workers results in three potential effects on staffing: it removes a specialist from the team because of the quarantine, increases the risk of patient exposure during the asymptomatic period, and increases the demand for other providers who are needed to fill the vacancy secondary to the quarantine of the at-risk provider.<sup>15</sup> The latter point is particularly important, because the pandemic nature of Covid-19 infection puts particular stress on the flexibility of the respiratory services as the demand shifts geographically. There are also savings related to not using PPE.<sup>2,16,22,28,29</sup> Outside the pandemic period, limiting the need for physical contact lowers the risk of patient cross-contamination via bedside RT. No clear prior solutions were available to emulate.<sup>30</sup>

In developing the eRT care model, we hypothesized that equipping RTs with a telemedicine platform would expand their services and scalability and enhance protection of health care workers from Covid-19 infection.<sup>14</sup> At the same time, we hoped that adapting an eRT service line to the increased demands, while demonstrating its value, would ensure the sustainability of the implementation, proposing a new durable paradigm for delivering care. Demonstrating sustainability and value of the eRT service beyond the immediate pandemic would show the new value of tele-critical care medicine (tele-CCM) and preserve its readiness for the next pandemic.<sup>8,9,12,13,16</sup> Now, more than 2 years into the program, we continue to see sustaining value in the eRT service line.

## **eRT Service**

By April 2020, the eRT service was integrated into an existing centralized location housed within the University of Pennsylvania Health System (UPHS) tele-ICU program (Penn E-lert). This was done by reallocating from our bedside RT staff. After starting with limited coverage, by May 2020, the final makeup of the eRT team consisted of seven registered RTs providing 24-7 coverage; the full-time and part-time staff represented 4.2 full-time equivalents (FTE).<sup>20</sup> Their average years of practice were  $17 \pm 6.5$  years, with  $10 \pm 6.6$  years in the current health care system. They had no prior experience working within the tele-ICU services. The eRT was in the same operations room as four 24-7 tele-ICU registered nurses (eRNs) and a nighttime critical care physician (eMD) and/or advanced care provider (eAPP). A standardized REDCap-based tool

was created to capture activities by the eRT according to them/their assessment ([Appendix, Exhibit 1](#)).<sup>31</sup>

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“ *Demonstrating sustainability and value of the eRT service beyond the immediate pandemic would show the new value of tele-CCM and preserve its readiness for the next pandemic. Now, more than 2 years into the program, we continue to see sustaining value in the eRT service line.*”

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The intervention template included the components of evidence-based care bundles, such as acute respiratory distress syndrome (ARDS), hyperoxia, and spontaneous breathing trials/ spontaneous awakening trials, as well as compliance assurance, taking over the task of the bedside RT (*eRT defer*), and assisting with respiratory demise ([Appendix, Exhibit 2](#)).<sup>24,32,33</sup> The workflow could be triggered by the eRT or staff of Penn E-lert or initiated by bedside providers.

The service was developed in several phases. We conducted a pilot in March 2020, exploring the feasibility of the project in terms of the RT being able to interact with UPHS using the telemedicine platform. At that time, we also asked colleagues to identify the potential area of intervention by using a brainstorming session involving staff from the tele-ICU core and RT initially rotating through the Penn E-lert physical location. This resulted in drafting the basic workflow that was prototyped during the next month with the group of eRTs. During that period, we determined the communication channels, established the scope of several tasks, and developed a tool to capture interventions.

One of the primary barriers was the lack of knowledge among bedside staff about how an eRT service would be deployed and how it might impact their ability to deliver patient care. This problem was overcome by word-of-mouth knowledge propagation about the service between eRTs and RTs, because eRTs frequently communicated with their bedside counterparts. Bedside RTs would further propagate the availability of the eRT service by word of mouth. Furthermore, we provided short briefings to the bedside RN and house staff about eRT service.

We also came to realize that the most effective communication channel is the phone, because this was the prevalent mode of communication between eRTs and bedside staff. This was contrary to our expectation of eRTs using tele-CCM means to connect; instead, unfamiliarity with this technology by bedside staff rendered this solution ineffective. Establishing the most effective way to communicate and propagate the knowledge of the eRT service was largely completed by May 2020. This peer-to-peer communication regarding eRTs and the offered services remained the most important way to maintain the knowledge about the service and provide updates about expansion of the services. We noticed that events for which Penn E-lert was particularly useful were frequently used by staff to advertise eRT services to their peers.

## Workflow

Within the context of the tele-ICU, seven RTs provided 24-7 coverage in the adult ICUs across seven hospitals and one long-term care facility and their respective ICUs (Table 1). The eRTs were scheduled to work a 12-hour shift, with one therapist covering an entire shift, Exhibit 9. The handover happened during the 10 minutes at the beginning of the shifts, which were scheduled at 7 a.m. and 7 p.m. This schedule mirrored the workflow of eRNs and eMDs in the Penn E-lert.

The interventions were completed using a remote eCareManager station (Philips, Amsterdam, Netherlands) because the tele-ICU platform converted in February 2021 to an Epic-based system (Verona, WI). Their service was set up in parallel to the ICU-based RTs. Each of the ICUs had one RT for approximately 6–10 beds, depending on the unit and the current acuity. One eRT covered remotely 15 various ICUs with a nominal bed capacity of 295. ICUs were initially specialized as Covid-19 (54%) or non-Covid-19 (46%) units, but in August 2020, hybrid units were introduced.

On site, the unit team was in charge of patients, which was a well-established practice. The eRTs were able to provide a host of services ([Appendix, Exhibits 1 and 2](#)). However, the bedside team was the primary team, and all eRT clinical interventions were carried out in communication with and after approval of the bedside team. As such, we called eRTs a *consultative service*, because

Table 1. Facilities Covered by the eRT Service Line\*

Hospital	Number of Beds	Number of eRT Interventions	ICU Description
Hospital 1	24	159	Medical ICU
Hospital 2	14	35	General ICU
Hospital 3	6	28	Long-term acute care
Hospital 4	22	2,889	Neuro ICU
	16	4,368	Surgical ICU
	36	5,586	Heart and vascular ICU
	12	1,578	Cardiac ICU
	24	5,574	Medical ICU
Hospital 5	24	214	General ICU
Hospital 6	16	269	Surgical and cardiac and neuro ICU
	13	581	Medical ICU
Hospital 7	16	1,773	Medical ICU
	24	2,013	Heart and vascular and cardiac ICU
	24	1,649	Trauma and surgical ICU
	24	1,548	Neuro ICU

\*Significant diversity in ICU profile and size is seen across hospitals, underscoring the ability of the telemedicine respiratory therapist (eRT) service line to adapt to various settings and to take into account the needs and culture of the particular unit. We found that over time, ICU diversity was reflected in the mix of services provided. Source: The authors

they work in capacity of providing service and sharing expertise upon request from bedside.<sup>20,21,24</sup> The eRTs also performed predetermined tasks related to compliance and safety, but, if prompted to intervene, they would contact the primary team to suggest changes in care delivery. The eRTs were not permitted to enter the orders without the knowledge of the primary team. This consultative model was agreed upon during the early phases of eRT service implementation in order to provide the least “traumatic” implementation, considering the concerns of the bedside team, which included the loss of autonomy and the potential for inadequate communication between the two teams that could lead to patient harm.

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“ Declining intubated *or* declining nonintubated were deemed urgent or emergent in 40% of cases when an eRT intervened, validating the ability of the eRT to remotely intervene and promptly address the clinical deterioration despite not being present in person.”

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Some of the eRTs’ actions were formalized to allow them to review patient records per predetermined tasks (e.g., proactive rounding). In addition, ad hoc requests for eRT services could come from the ICUs (site trigger), tele-CCM platform (eCare), or Penn E-lert staff, or by an algorithmic electronic medical record (EMR) sniffer aimed at the detection of ARDS.<sup>34</sup> Bedside staff could reach out to the eRT directly by phone, tele-CCM platform, or asynchronous texting tool. Finally, eRTs could be summoned immediately by staff pressing the care team’s emergency button in the patient’s room. Review of EMRs, a direct remote audio-visual inspection of the patient room and ventilators, and direct interaction with unit staff could be concurrently employed to accomplish a task. After the review of the relevant documentation, the eRT could determine the need for communication with the bedside team. The expediency of response was deemed routine if the required response time was within 2 hours, urgent if the required response time was within 30 minutes, or emergent for an immediate response.

The tasks for eRTs were precisely defined in April 2020 and changed little over the next 16 months ([Appendix, Exhibit 3](#)). An incidental workflow benefit associated with the eRT model is that the need to don and doff PPE is eliminated, saving about 12 minutes to complete that procedure, which represents a cost of about \$8.04 per event, on the basis of the \$40.20 per hour compensation for the eRTs and the RTs. That time, of course, can then be used for other tasks ([Appendix, Exhibit 9](#)).

## Results

The data to assess the eRT service were gathered through a postintervention survey that the eRT was asked to submit. The data were collected between May 1, 2020, and August 31, 2021, using the final electronic REDCap database ([Appendix, Exhibit 4](#)). The Statistical Analysis is provided in the [Appendix, Exhibit 5](#).<sup>31</sup>



## *eRT Service Health Care Delivery Model*

A total of 31,609 interventions took place between May 1, 2020, and August 31, 2021. Almost all interventions, 97.80%, were routinely related to the established workflows, while 1.90% were urgent and 0.30% emergent (Table 2). The number of urgent cases decreased slightly during the observation period, but it was variable. The first peak in urgent cases coincided with the May–August Covid-19 case surge but after that, the variation in the frequency of urgent cases did not increase during subsequent waves. The frequency of emergent cases remained similar between May 2020 and August 2021.

Most of the interventions were related to *eRT defer or compliance* (Figure 1A). The bulk of interventions were triggered during *proactive rounding* (71.2%).

Other interventions were triggered by *bedside providers* (10.2%) or by the tele-ICU staff (*eTriage*; 3.3%), directing the attention of an eRT to clinical problems (Table 3).

**Table 2. Total Count and Total Percentage of eRT Interactions Based on Expectancy\***

Expectancy	Interaction Focus	Total Count	Percent of Total	Percent Cumulative
Routine	Clinical intervention	2,395	7.4	7.4
	Proactive rounding	27,706	85.9	93.3
	Education	51	0.2	93.5
	Safety	174	0.5	94.0
	Debrief	8	0.0	94.0
	Recording	833	2.6	96.6
	Other	380	1.2	97.8
	Urgent	Clinical intervention	199	0.6
Proactive rounding		376	1.2	99.6
Education		4	0.0	99.6
Safety		12	0.0	99.6
Debrief		0	0.0	99.6
Recording		7	0.0	99.6
Other		20	0.1	99.7
Emergent		Clinical intervention	28	0.1
	Proactive rounding	72	0.2	100.0
	Education	0	0.0	100.0
	Safety	3	0.0	100.0
	Debrief	0	0.0	100.0
	Recording	1	0.0	100.0
	Other	1	0.0	100.0

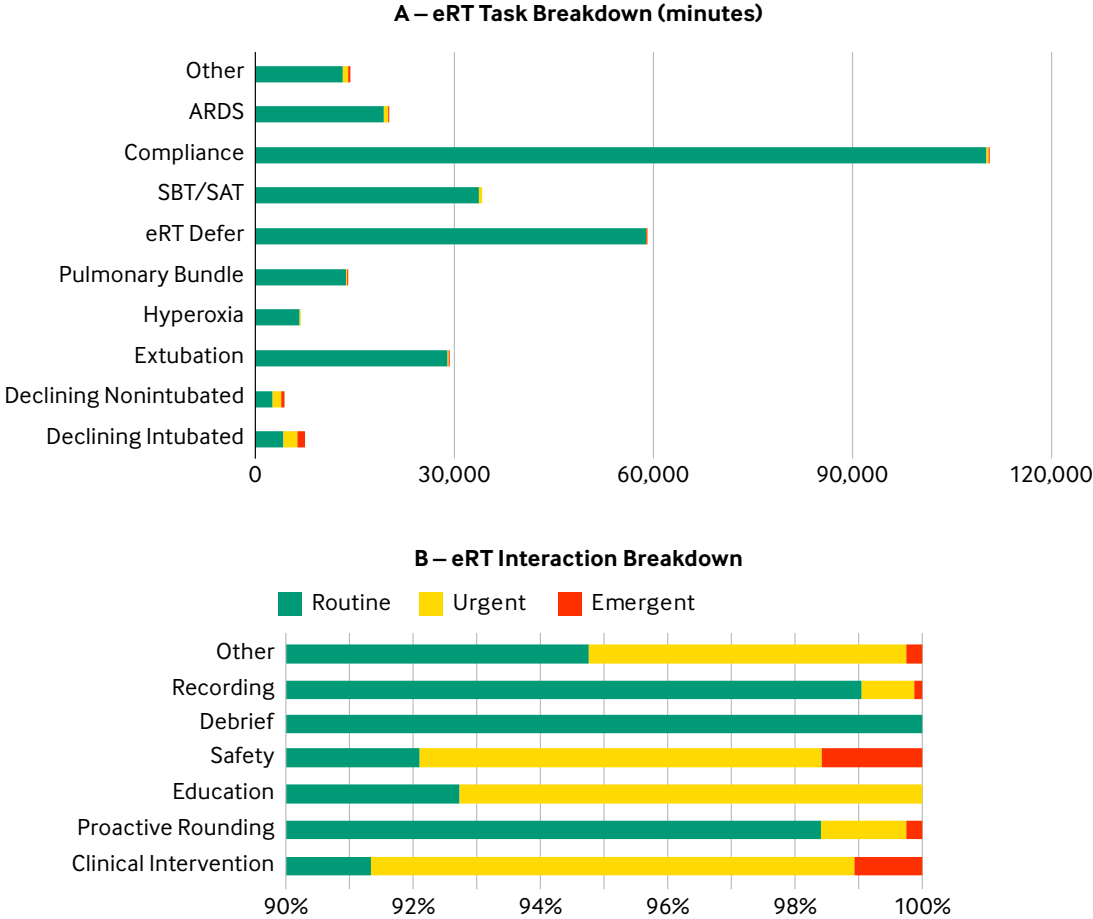
\*A significant part of the telemedicine respiratory therapist (eRT) service was proactive rounding to ensure compliance and implementation of the best practices for routine tasks. Of course, such rounding also led to urgent and emergent interactions. Source: The authors

Clinical intervention and safety had a higher percentage of tasks deemed urgent/emergent (Figure 1B). Most of the interventions took place during nights and weekends (Figure 1C and 1D). Higher demand for emergent/urgent eRT services occurred during weekends and at night. These trends reflect the workflow of the hospital, with fewer staff assigned to work during these times.

FIGURE 1

### Data Related to Interventions by the eRT Service Line

Most of the telemedicine respiratory therapist (eRT) tasks were eRT defer- (completed by the eRT service instead of the bedside respiratory therapist) or compliance-related and were executed overwhelmingly as routine, while declining patients were treated as urgent and emergent with greater frequency. The data suggest that the eRT service can respond to clinical deterioration on demand. Clinical intervention and safety represent the two categories with the most urgent interventions, validating our results because such a breakdown is expected (A and B). There was a spike in the need for intervention at night (C) and over the weekend (D), reflecting changes in bedside staffing during hospital operations.



ARDS = acute respiratory distress syndrome, SAT = spontaneous awakening trial, SBT = spontaneous breathing trial. In (D), S = Sunday, M = Monday, T = Tuesday, W = Wednesday, T = Thursday, F = Friday, and S = Saturday represent the days of the week in sequential order.

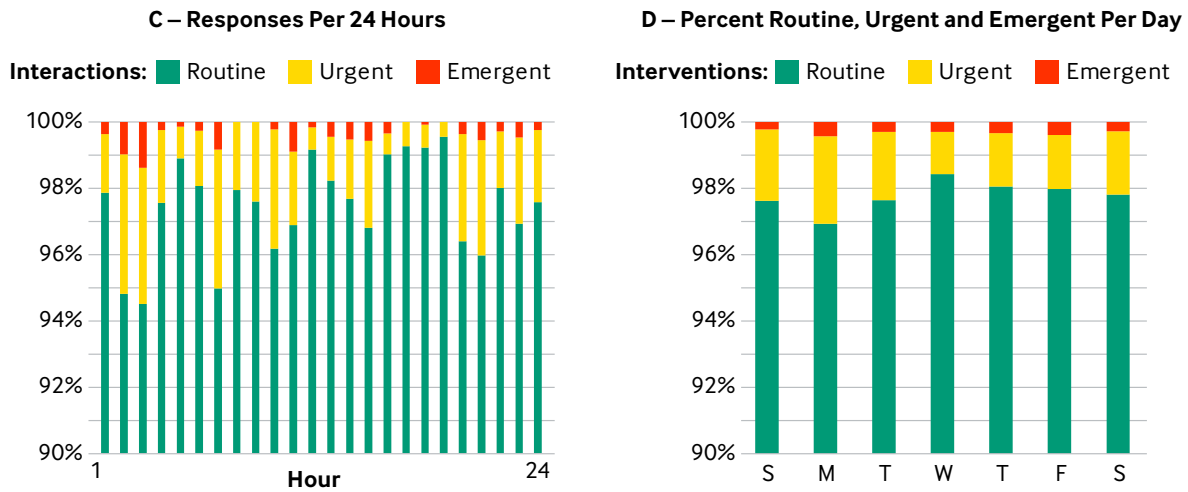
Source: The authors

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FIGURE 1

Continued



There were statistically significant differences in time devoted to the tasks depending on the task expediency ([Appendix, Exhibit 6](#)).

In 51.2% of all interventions, no communication took place between the eRT and other clinical staff. The communication between eRTs and ICU-based RTs took place in 36.7% (n = 11,608) of all database entries (31,609), followed by communication with house staff (7.2%), APPs (5.2%), and nurses (1.6%) ([Appendix, Exhibit 7A](#)). Most of the communication involved a single bedside provider, but in 4.1% of all communications, several stakeholders were involved simultaneously, underscoring the ability of the eRT service to engage multiple stakeholders remotely. Most of the interactions took place over the telephone (81.4%), followed by secure texting platforms (16%), and tele-CCM platforms (1.4%); the remaining were negligible. Most of the time spent on the interventions involved *compliance* or *eRT defer* ([Appendix, Exhibit 7B](#)).

Table 3. eRT Trigger Distributions\*

Triggers	Total Count	Percent of Total	Percent Cumulative
Proactive Rounding	23,169	71.2	71.2
Site Initiated			
Push button	44	0.1	71.3
Virtual	46	0.1	71.4
Phone call/text message	3,251	10.0	81.4
Sniffer/Dashboard Tool (ARDS, Sepsis, etc.)	3,032	9.3	90.7
Tele-ICU Platform– Generated Alert	1,911	6.0	96.7
Penn E-lert Staff Triage	1,068	3.3	100.0

\*eRT = telemedicine respiratory therapist, ARDS = acute respiratory distress syndrome. Source: The authors

The clinical tasks focused on *declining nonintubated*, *extubation*, and *declining intubated* ([Appendix, Exhibit 7B](#)). Of particular note, *declining intubated* or *declining nonintubated* were deemed urgent or emergent in 40% of cases when an eRT intervened, validating the ability of an eRT to remotely intervene and promptly address the clinical deterioration despite not being present in person ([Appendix, Exhibit 7C](#)).

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“ *Postaction interviews often showed that bedside staff were surprised by how flexibly and effectively the eRT care delivery service functioned. Perception of acceptance by the bedside staff was overwhelmingly positive, because only 2.8% of interactions were rejected straightforwardly, as judged by eRTs.*”

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During the initial stages of implementation of the eRT service, several stakeholders expressed their concern regarding the ability to deliver prompt and effective respiratory service virtually. Although we did not measure the impacts of these interventions in a direct way, postaction interviews often showed that bedside staff were surprised by how flexibly and effectively the eRT care delivery service functioned. Perception of acceptance by the bedside staff was overwhelmingly positive, because only 2.8% of interactions were rejected straightforwardly, as judged by eRTs.

### *The Involvement of the eRT Service in Patients with and without Covid-19*

During the study period, 15% of all eRT interventions were related to Covid-19. The number of interventions trailed closely the demand of Covid-19-related interventions by eRTs in the system, expressed as total patients with Covid-19 or total admissions ([Appendix, Exhibit 8](#)). This suggests that eRT workload trails hospital-wide and can adapt, suggesting eRT flexibility. Overall, time spent on different tasks was not different between patients with Covid-19 and without Covid-19 because of the high data variability when split into the subgroups ([Appendix, Exhibit 8](#)).

### *Cost Savings Related to eRT*

The cost reduction attributed to the eRT service introduction could stem from two sources: the costs saved by transferring the RT service from the ICU bedside to a remote tele-ICU, resulting in freeing bedside RT to other tasks, and the costs saved from decreasing PPE utilization. Assuming that eRTs can execute *eRT defer*, *declining intubated*, *declining nonintubated*, *extubating check*, and *surveillance of the newly extubating* to virtual service only and in lieu of bedside RT, a total of \$79,095 was saved in cost related to compensation. This number factored in the savings resulting from saving time for donning the PPE because eRTs could perform many tasks remotely.

What remains to be demonstrated is whether the eRT can conduct the same task in less time than can the bedside RT. The American Association for Respiratory Care standards stipulate the time needed to perform certain tasks by an eRT. When we measured similar tasks performed by

an eRT, the time devoted to some of them seems to be shorter. For example, assessment of the patient may take up to 15 minutes, but our eRT service executed the task in a shorter period of time ([Appendix, Exhibit 6](#)).<sup>35</sup> A task described as monitoring may take up to 15 minutes according to the standard, but again, the eRT could perform this task more quickly.<sup>35</sup>

Additional savings were related to saved PPE due to the engagement of the eRT service and freeing the bedside RT service and amounted to \$119,390.56.<sup>36</sup> This assumes that bedside RT used this time to perform other activities. As we did not measure bedside workflow, we cannot quantify the impact; however, considering that eRTs were deployed, among other reasons, to alleviate bedside RT shortage secondary to pandemic demand, it is likely that that time will be used by RT.

## Analysis

Transformation of a pandemic-precipitated innovation into a scalable and durable operation requires proving its universal value. In this respect, innovation shapes potential solutions, but the adoption process is critical for long-term implementation.<sup>8</sup> In this article, we described the implementation process of the eRT service, a novel service line employing the RT using tele-critical care infrastructure to augment and enrich the delivery of care to patients in our health care system. The deployment of such a system catalyzed by a catastrophic event occurs in four phases: *conceptual, improvisation, growth, and maturation*.<sup>13</sup> Here, we focus on maturation services.

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“*eRTs delivered more than 36,000 interventions over the reported time. This is equal to 98 interventions in a 24-hour period. RT leadership estimates that this is 50%–75% of the interventions conducted during the same time by bedside RT.*”

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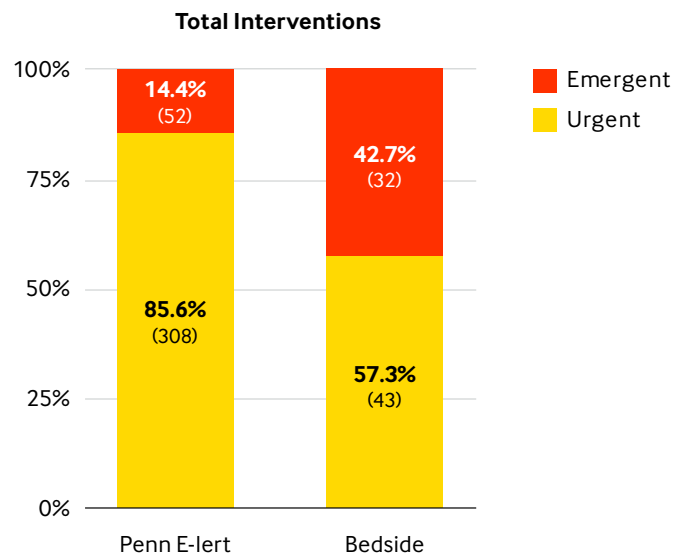
Traditionally, RTs provide care on the basis of physician orders, well-recognized standards of care (ARDS and lowering high fraction of inspired oxygen [FiO<sub>2</sub>]), and preexisting protocols.<sup>21</sup> Here, we equipped them to deliver their services remotely via tele-CCM. To our advantage, we used the existing technological and operational infrastructure of Penn E-lert (Penn Medicine’s electronic tele-ICU that was established in 2004), instead of adopting other commercially available tele-CCM systems. Integrating the eRT service into an existing infrastructure avoided high initial costs and the typical growing pains of developing an entirely new service line.

The value proposition of the deployment can be measured in several ways, but notably, the metrics have evolved little since the initial deployment.<sup>26</sup> In our case, eRTs delivered more than 36,000 interventions over the reported time. This is equal to 98 interventions in a 24-hour period. RT leadership estimates that this is 50%–75% of the interventions conducted during the same time by bedside RT. Urgent and emergent calls directly testify to situations in which eRTs were engaged to solve emerging clinical problems associated with patient deterioration. They are usually classified as *worsening clinical status*. Out of 1,091 such

FIGURE 2

## Urgent and Emergent Interventions by eRT Service Line and Bedside RTs

The telemedicine respiratory therapist (eRT) service frequently addressed urgent clinical problems secondary to their own clinical review, while in cases of emergent problems, the initiation was almost equally distributed between bedside and eRT staff when all interventions were considered. This demonstrates the ability of the Penn eRT service to identify the urgent medical problem ahead of the bedside team.



Source: The authors

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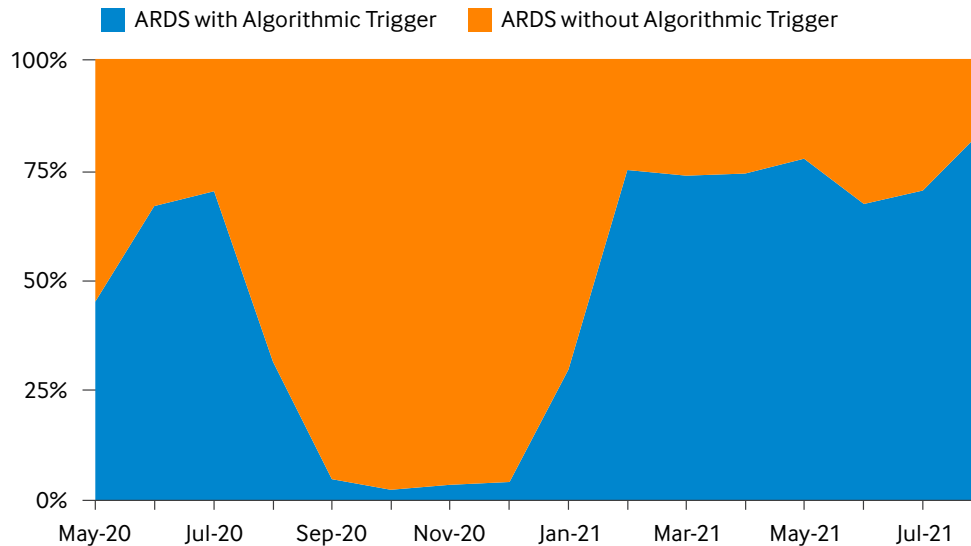
interventions, 70.5% were initiated by eRT/Penn E-lert staff spotting and reacting to them earlier than did bedside staff (Figure 2). In effect, they represent situations in which development of a more severe clinical condition was interrupted by earlier eRT intervention. These interventions were initiated by the eRT via numerous modalities (tele-CCM console and algorithmic during routine review of cases).

Another source of value is compliance with the most-established, evidence-based protocols. Enforcing compliance with low stretch ventilation protocols in the case of patients diagnosed with ARDS and assessing the necessity for high FiO<sub>2</sub> are directly related to the improved mortality.<sup>25</sup> Most important, the eRT service detected unfavorable practice patterns in ARDS treatment and intervened before the ARDS algorithmic trigger was activated; this demonstrates that proactive chart review focused on targeted, high-value intervention can result in improved outcomes over a solution using algorithms and system design to respond to it (Figure 3). We attribute the effectiveness of the eRT-driven process to an ability to detect the ARDS cases before the algorithm but also to the eRTs' ability to directly contact the bedside staff and to advocate for ventilatory adjustment in compliance with low stretch protocol. Ventilation of the

FIGURE 3

## Detection and Intervention by eRT Service and Algorithmic Trigger in ARDS Care

Of the 2,685 acute respiratory distress syndrome (ARDS) interactions that occurred between May 1, 2020, and August 31, 2021, 911 (840 routine, 71 urgent, and no emergent) were addressed by a telemedicine respiratory therapist (eRT) in response to a nudge produced by an algorithmic ARDS detection tool, while 1,774 (1,766 routine, 7 urgent, and 1 emergent) were responded to by eRT staff preceding the alert triggered by algorithmic ARDS detection. This suggests that the eRT provided a valuable service in harm reduction (early implementation of the low tidal ventilatory protocol) in a patient with ARDS. This was accomplished mostly during proactive rounding, and it was of important value to the health care system.



Source: The authors

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patient with above-optimal tidal volume results in harm quantified per hour, so accelerating the implementation of low stretch ventilation and reducing the harm by even a couple of hours has a measurable impact on a more favorable outcome.<sup>33</sup> Providing another layer of compliance with best practice by the eRT service is part of increasing system redundancy and supporting the mission of Penn Medicine to become a high-reliability organization.

We demonstrated that in 2,685 cases, the eRT service reduced harm to patients by aiding implementation of the low stretch protocol in patients with ARDS, which is associated with a reduction in mortality and length of stay.<sup>33</sup> An analogous conclusion can be drawn for the hyperoxia protocols.<sup>37</sup> Other benefits of the eRT service line are staff flexibility, because bedside staff deferred tasks to eRTs regularly, with increased frequency after 3 months, freeing the bedside staff to focus on in-person care. Of note, these deferred tasks were executed more effectively, timewise, by eRTs than by the bedside staff. This is particularly true for isolated patients with Covid-19, who required additional time from staff who were following isolation protocols.<sup>4,15,17,36</sup> The financial gain related to PPE expenses is relatively small,<sup>36</sup> but compliance with documentation and best practices

produces the benefits of reducing the margin for errors, while also reducing potential regulatory noncompliance.<sup>33</sup>

Perception of the acceptance and utilization of the eRTs by care team stakeholders was present on our survey's provider and recipient side. Only a small number of interventions were just acknowledged, while in only 52 cases out of all judged interventions were the eRT recommendations straightforwardly rejected. This is remarkable, because the implementation of tele-CCM services may sometimes encounter mistrust as a barrier to operational success.

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“ *The eRT service detected unfavorable practice patterns in ARDS treatment and intervened before the ARDS algorithmic trigger was activated; this demonstrates that proactive chart review focused on targeted, high-value intervention can result in improved outcomes over a solution using algorithms and system design to respond to it.*”

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Our study has several limitations. First, we used surveys to determine the impact of the eRT service. The survey respondent was strongly advised to describe all interventions, but unfortunately, not all interventions were captured. We estimated compliance with survey registration at 70%–80%. Also, the frequency of entries indicating *other* (5.8%) increased during the study period, suggesting that we could not devise all of the potential tasks as the eRT staff could classified. Therefore, analyzing *other* may yield other unique ways to use the eRT service line. This is of particular importance, because Penn E-lert staff continuously explored options to deliver more effective and valuable care.<sup>38</sup> The effect of Covid-19 is variable, because caseloads have varied timewise and are ICU dependent. During observation periods, several other forces affected the hospital's workflow with unclear effects on data. Finally, there were significant changes to the eRT model secondary to attrition and retirement. These changes may have put significantly more pressure on the eRT service line, but the effect would be difficult to quantify.

The creation of the eRT service required the identification of pivotal stakeholders. RTs were supportive of this model. The pandemic alleviated some implementation hesitancy because Covid-19 was of significantly greater concern. Staff shortages were another factor allowing us to make a case for the service. The financial argument was difficult considering that the service was not net positive as judged by some stakeholders in our system, but we stressed the benefits in soft outcomes, safety, quality improvement, and the need for staff flexibility during the pandemic. The major perceived expense was related to compensation for 4.2 FTE of RTs who were relocated from hospital staff to the eRT service. However, no new staff were hired to support the eRT program, and the RT positions were not backfilled with new hires. The therapists assigned to the eRT service at the beginning of the pandemic had preexisting conditions preventing them from working in a Covid-19 environment, so this action preserved them as a workforce during the pandemic.

Moreover, during the process of implementation, Penn Medicine discovered additional value in the service and decided to extend the program as part of the creation of a high-reliability organization.

The costs associated with implementing the service were low, because the existing structure was already in place. Low upfront cost implementation costs removed the implementation barrier, but the demonstration of the safety and quality of the eRT service allowed for service maturation and preservation beyond the acute pandemic.<sup>8,13,25</sup>

Our quality assurance projects were performed in a health care system with a well-established tele-ICU presence. Other less-established systems may face culture and deployment issues. Moreover, as the availability and affordability of the tele-ICU platform continue to increase, our model represents a universal principle of augmenting hospital services, especially during seasonal increases in demand or emergencies.<sup>14,16,24</sup> This may mitigate the effect of a pandemic on canceling routine and semiurgent care delivery, as was reported by U.S. hospitals frequently.<sup>3</sup> As of April 2022, we are piloting a project with one eRT FTE investigating whether compliance, ARDS, and other targeted intervention will result in quantifiable improvement in patient care at a lower expenditure related to staffing.

**Krzysztof Laudanski, MD, PhD, MA, FCCM, MHC**

Assistant Professor, Department of Anesthesiology and Critical Care, Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania, USA

Senior Fellow, Leonard Davis Institute for Health Economics, University of Pennsylvania, Philadelphia, Pennsylvania, USA

Assistant Professor, Department of Neurology, Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania, USA

**Michael Scott, MBChB, FRCP, FRCA, FFICM**

Division Chief, Critical Care Medicine, Department of Anesthesiology, Perelman School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania, USA

Medical Director, Penn E-lert Tele-Medicine, Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania, USA

Professor, Department of Anesthesiology and Critical Care, Perelman School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania, USA

**Ann Marie Hufferberger, DBA, RN, NEA-BC**

Director, Center for Connected Care, Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania, USA

**Justin Wain**

Medical Student, Campbell University School of Osteopathic Medicine, Buies Creek, North Carolina, USA

**C. William Hanson III, MD**

Chief Medical Information Officer and Vice President, University of Pennsylvania Health System, Philadelphia, Pennsylvania, USA



## Appendix

[eRT Service Line Exhibits 1-9](#)

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