eICU Reduces Mortality in STEMI Patients in Resource-Limited Areas

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Although health care is evolving rapidly in urban regions in the developing countries, it continues to pose a formidable challenge in the semiurban and rural areas [1]. In particular, intensive care is a demanding service that mandates round-the-clock availability of cutting-edge technology and skilled intensivists with a need for substantial investment in the infrastructure. The increasing age of the population has added to the demand for the intensive care services. India spends >5% of its gross domestic product on health care compared with 15% in the United States; there are 0.6 physicians per 1,000 population in India compared with 2.4/1,000 in the United States [2]. Out of total hospital deaths, approximately 10% are due to delayed intensive care unit (ICU) services or mistakes made thereof. The available ICUs are usually run by 1 physician who cannot cover it 24 h, 365 days a year. Night cover duty doctors, even if available, lack optimum critical care expertise, and this expertise gap is particularly noticeable in the emergency situations such as ST-segment elevation myocardial infarction (STEMI) and other cardiovascular emergencies. MI has become the most important health problem in the developing countries [3], wherein the early reperfusion is mandatory for reduction in morbidity and mortality [4,5]. We explored whether a remotely monitored ICU (electronic ICU [eICU]) would bridge this demand-supply gap in the cities where neither contemporary emergency care infrastructure nor critical care expertise are available. To evaluate the efficacy of an eICU model of service and intervention for the early diagnosis of STEMI and prompt initiation of thrombolytic therapy, mortality during a 12-month eICU period was compared with the mortality in 12 months preceding eICU establishment.

In this retrospective observational study, an eICU model was established in a 7-bed critical care unit in Fortis Hospital (Dehradun), where expert cardiac manpower was not available. The nearest equipped healthcare center was around a 10-h journey by surface transport. An eICU was established with a remotely controlled command center located in the Fortis Heart Institute and Research Center, New Delhi, with complete cardiology and critical care coverage. The eICU had 24/7 coverage from April 2013 to March 2014. A total of 145 patients were admitted under the eICU coverage for STEMI and new onset left bundle branch block; MI and left bundle branch block were grouped together as STEMI. The eICU had complete access to patients' real-time vitals, hemodynamic parameters, electrocardiograms, and lab values; audiovisuals and smart alerts were appropriately engineered. As per the American College of Cardiology Foundation/American Heart Association 2013 guideline, thrombolytic treatment was initiated within 30 min of arrival in appropriate patients. During and after thrombolysis, close monitoring was done for potential complications and, wherever deemed necessary, consults were given and interventions made. Data analysis was performed for patients admitted to the eICU model. The comparison of outcomes was undertaken with 134 patients of STEMI and new onset left bundle branch block admitted during the period of April 2012 and March 2013 before the establishment of the eICU.

During the eICU-supported period, all patients who came with chest pain were actively screened through eICU for potential acute coronary syndrome by the cardiologists at the central command station. History was recorded; electrocardiograms were evaluated remotely; and patient demographics, including risk factors, hemodynamic parameters, and contraindication to thrombolysis, were taken into account with the target of initiating thrombolysis in patients with STEMI within 30 min of arrival (Table 1). Patients were monitored for any complication, and, if deemed necessary, suggestions were made for the same.

All-cause and cardiovascular mortality was recorded at 30 days in all cases. Descriptive analysis was carried out. Categorical variables were presented as numbers and percentages and continuous variables as mean ± SD. Between-groups comparison was performed by applying chi-squared statistic or Fisher exact test for categorical data and Student *t* test for continuous variables. Statistical significance was assumed at a value of $p = 0.05$. All statistical analyses were performed with SPSS for Windows (version 13.0, IBM, Armonk, New York). In addition, cost analysis was performed for eICU services incurred by the hospital on actual payout, which was fixed at INR 500 per day per bed.

The eICU facility was associated with significant improvement in mortality. The 30-day mortality of 16.4% in the pre-eICU period in 134 STEMI patients was reduced to 4.8% in 145 STEMI patients admitted during the eICU care model; a reduction of >70% in mortality ($p = 0.001$). Of the 134 patients in the pre-eICU period, 68 patients received thrombolytic therapy with the mean door-to-needle (D2N) time of 178.63 min, compared with 26.23 min in 145 patients in the post-eICU period ($p < 0.001$) (Table 2). Mortality, even in the pre-eICU thrombolyzed subgroup, 9 of 68 (13.2%) was significantly higher as compared to the post-eICU period (7 of 145, 4.8%; $p = 0.029$). In the

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TABLE 1. Clinical and biochemistry in patients presenting with STEMI

	Pre-eICU	Post-eICU	p Value
n	134	145	—
Age, yrs	55.61 ± 9.54	56.47 ± 8.91	0.438
Family history of CAD	67 (50)	72 (49.66)	0.954
Previous history of CAD	9 (6.72)	11 (7.59)	0.778
Previous revascularization	2 (1.49)	3 (2.07)	0.717
DM	63 (47.01)	68 (46.90)	0.984
HTN	37 (27.61)	41 (28.28)	0.902
Smoking	55 (41.04)	59 (40.69)	0.952
Dyslipidemia	89 (66.41)	88 (60.69)	0.321
BMI, kg/m^2	26.63 ± 3.94	26.65 ± 3.88	0.964
HR, beats/min	109.01 ± 27.71	105.50 ± 26.79	0.282
SBP, mm Hg	117.33 ± 27.81	118.15 ± 27.04	0.802
DBP, mm Hg	70.60 ± 18.45	73.81 ± 19.36	0.159
SCr, mg/dl	1.57 ± 0.71	1.59 ± 0.70	0.802
Hb, g/dl	11.34 ± 1.96	11.23 ± 1.93	0.650
RBS, mg/dl	155.37 ± 73.26	156.10 ± 65.75	0.930
Chest pain at presentation	134 (100)	145 (100)	—
APACHE II	8.27 ± 1.86	8.50 ± 1.75	0.292

Values are mean ± SD or n (%).

APACHE II, Acute Physiology and Chronic Health Evaluation II score; BMI, body mass index; CAD, coronary artery disease; DBP, diastolic blood pressure; DM, diabetes mellitus; eICU, electronic intensive care unit; Hb, hemoglobin; HR, heart rate; HTN, hypertension; RBS, random blood sugar; SBP, systolic blood pressure; SCr, serum creatinine; STEMI, ST-segment elevation myocardial infarction.

pre-eICU period, the appropriate diagnosis of STEMI and thrombolytic therapy was not given in 66 of 134 patients as compared to none in the post-eICU phase ($p < 0.001$); mortality of 19.7% (13 of 66) was recorded in this group of patients ($p < 0.001$).

The patient population in pre- and post-eICU groups did not differ significantly when compared for age, diabetes mellitus, hypertension, renal dysfunction, dyslipidemia, smoking, family history of coronary artery disease, previous history of coronary artery disease, and previous revascularization (Table 1). The mean APACHE II (Acute Physiology and Chronic Health Evaluation II) score of patients admitted in the pre- and post-eICU phases were 8.27 and 8.50, and mean age was 55.61 versus 56.47 years, respectively; cardiogenic shock was observed in 20 patients in the pre-eICU period as compared to 15 in the post-eICU period (p = NS). Ventricular tachyarrhythmias/ventricular fibrillations were observed in 16 and 12 patients, and atrial fibrillations/supraventricular tachycardias in 20 and 22 patients in the pre- and post-eICU periods (p = NS). The hospital incurred a total expense of INR 224,750 for supporting these patients through eICU, which averaged to INR 1,550 per patient (i.e., equivalent to US$26 per patient).

Any regional medical system must seek to enable rapid recognition and timely reperfusion of patients with STEMI. System delays to reperfusion are correlated with higher rates of mortality and morbidity [6–10]. In the 2004 American College of Cardiology/American Heart Association STEMI guideline, the appropriate and timely use of some form of reperfusion therapy was stated as being more important than the choice of therapy [11], and the guideline emphasized the delivery of reperfusion therapy to each individual STEMI patient as rapidly as possible. In the eICU model, the same principle was applied at a remote center lacking in timely diagnosis of STEMI wherein the clinical expertise was not available. The crucial eICU support made a significant change in the outcome of patients who otherwise would have received either delayed thrombolysis or might not have received it at all. Continuous monitoring and support by the eICU ensured appropriate screening of all patients admitted with chest pain. The electrocardiograms were evaluated and patients received thrombolytic therapy if there was no contraindication. Furthermore, D2N time was significantly reduced to 26.23 min, which is >85% shorter than D2N for the pre-eICU period. During and after thrombolysis, close monitoring of patients was done, and, whenever necessary, the command center appropriately intervened. Based on these observations, it seems that the 2 most important factors in decreasing the mortality in STEMI were the appropriate use of thrombolytic therapy and reduction in the D2N time, and such a strategy might enable a cardiologist or intensivist at a remote distance to identify the patients in need of thrombolysis and also ensure that it is instituted in the shortest time frame to reduce mortality at centers lacking requisite expertise.

TABLE 2. In-hospital therapy and outcome during hospital stay

	Pre-eICU	Post-eICU	p Value
In-hospital therapy			
Aspirin	134 (100)	145 (100)	—
Clopidogrel	134 (100)	145 (100)	—
UFH/LMWH	134 (100)	145 (100)	—
ACE inhibitors	49 (36.57)	52 (35.87)	0.902
Beta-blockers	111 (82.84)	115 (79.31)	0.453
Statins	134 (100)	145 (100)	—
Thrombolysis	68 (50.74)	145 (100)	$<$0.001*
Door-to-needle time, min	178.63 $\pm$ 39.07	26.23 $\pm$ 2.68	$<$0.001*
In-hospital outcome			
Cardiogenic shock	20 (14.92)	15 (10.35)	0.248
VT/VF	16 (11.94)	12 (8.28)	0.309
AF/SVT	20 (14.92)	22 (15.17)	0.954
CVA in thrombolyzed patients	1 (1.47)	1 (0.69)	0.566
Hospital stay, d	4.96 $\pm$ 1.18	4.69 $\pm$ 1.19	0.056
Mortality	22 (16.4) (9 in thrombolyzed and 13 in nonthrombolyzed group)	7 (4.8)	0.001*

Values are n (%) or mean $\pm$ SD.
ACE, angiotensin-converting enzyme; AF, atrial fibrillation; CVA, cerebrovascular accident; eICU, electronic intensive care unit; LMWH, low molecular weight heparin; SVT, supra ventricular tachycardia; UFH, unfractionated heparin; VF, ventricular fibrillation; VT, ventricular tachycardia.
*Statistically significant.

CONCLUSIONS

The developing world is plagued by an interesting paradox of limited infrastructure and poor specialty skills, while grappling with an explosion of the disease burden. Cardiac diseases and MI prevalence are on the rise in low- and middle-income countries. It is also important to note that in India, 80% of patients pay for their medical care out of pocket without insurance support. It becomes necessary not just to treat without a need to move to specialized centers, but also provide appropriate care at the ill-equipped centers. We describe specific intervention in thrombolysis, where not only initiation of thrombolytic treatment was supported remotely by eICU, but the D2N time in STEMI was significantly reduced to achieve significant mortality benefit. Whereas this study specifically focuses on a specific intervention related to MI treatment, the eICU model can be used to intervene in other life-threatening cardiac and noncardiac emergencies such as arrhythmia management and cardiopulmonary resuscitation.

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