ORIGINAL ARTICLE

Cost Analysis and Utilization of Mechanical Ventilators in Intensive Care Units of South India

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ABSTRACT

In order to optimize resource consumption and resource distribution especially costly and vital equipment, it is necessary to calculate and compare cost and revenue center areas in ICUs. The study was conducted in six Adult ICUs of a tertiary care teaching hospital in Southern India during three month study period actual revenue and utilization data of mechanical ventilators' in ICUs' were collected. The contribution margin followed by cost-volume-profit calculation was performed. The 666 patients requiring mechanical ventilation were admitted in six Adult ICUs over a period of three months. Medical ICU had a maximum number of patient days as compared with other ICUs the allocation was skewed and the two ICUs were over utilizing the resources. The ventilators proper allocation and utilization add to the profit margin of the hospital as well as decrease the chance of nosocomial infections.

MeSH terms: Hospitals, Intensive care unit, cost analysis, allocation of resources, ventilators, health service, Indian.

INTRODUCTION

Intensive care unit consumes nearly 20percent of hospital resources but caters to only limited number of patients still works as a revenue center for the hospital[1]. To optimize resource consumption and to have uniformity in distributing resources especially costly and vital equipment, it becomes necessary to calculate and compare cost center and revenue center areas in ICU. Studies have reported that world's population is moving towards aging, henceforth, we require judicious allocation and utilization of all available resources in the health sector. Until resources are allocated and utilized optimally, it will certainly add up to the cost to the hospital[2–4]. According to Yasaitis L, Fisher ES, Skinner JS & Chandra A, it has been found that the demand for mechanical ventilator has grown exponentially but are we prepared to handle such more requirements in future[5,6].

However, ventilators are the critical equipment for ICU but over or under procurement of such equipment for ICU may lead to problems for either the organization or the patient[7]. It becomes essential for the administration team to decide based on the scientific approach that which ICU need more ventilator and which may require less and what is the contribution of ventilators in profit rise. To answer these questions this study was carried out at a tertiary care teaching hospital in south India, to find the associated costs, contribution margin, profitability and utilization of one of the most expensive equipment used in ICU i.e. ventilators.

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METHODOLOGY

This study was conducted in six Adult ICUs of a tertiary care teaching hospital in south India. The study was reviewed and approved by the Institutional Review Committee and Ethics Committee (IEC 55/2014) and have therefore been performedin accordance with ethical standards. There were 6 Adult ICUs as a closed unit with 83 intensive care beds. The study includes Surgical ICU (ICU 1), Medical ICU (ICU 2), Neurology ICU, Burns ICU, Casualty ICU and Cardiac ICU. A doctor to patient ratio of 1:4 and a nurse to patient ratio of 1:1 are maintained round the clock. All patients admitted to the Adult ICUs were retrospectively studied for a duration of three months. The data on gender, hospital length of stay, ICU length of stay, payer, duration on a ventilator, no. of ventilator circuits used, charges of ventilator per day, charges of ventilator filters and charges on any other consumable used for mechanical ventilator was collected through patient's hospital record and final bill. Actual Revenue and utilization data of mechanical ventilators' in ICUs' was collected from nurse record, billing record and IT department. Data on fixed and variable cost of mechanical ventilators in ICUs were obtained from finance, administration, biomedical department, general maintenance, electrical department and general store department of the hospital. The collected data was categorized as 1) direct and indirect costs and 2) fixed and variable costs[8]. All patients on mechanical ventilators, irrespective of the underlying diagnosis and length of stay were included in the study. The cost of mechanical ventilator was calculated periodically for all the patients individually.

RESULTS

A total of 1494 patients got admitted in 6 ICUs out of this 666 patient required mechanical ventilation on 83 ICU beds and 46 ventilators, 2:1 for a bed to ventilator ratio. All the patients on mechanical ventilation were considered for the study except those who got intubated during resuscitation and used a ventilator for less than 30 minutes were declared dead and were not billed. Surgical ICU had the highest number of beds i.e. 17 in number whereas the

Burns ICU and Cardiac ICU has the least 12 number of bed. A maximum number of ventilators were present in Medical ICU (15 nos.) and minimum in Burns ICU (2 nos.). Ventilator to bed ratio was 1:1 in Medical ICU, maximum ratio while in Burns ICU it was 1:6 which is the least among all the ICU.

It was found that overall male required more mechanical ventilation days as compared to female admissions (male 64%, Female 35%) requiring in all the adult ICUs except in Burns ICU where female patients (Female 61%, Male 39%) admission, requiring mechanical ventilation was more as compared to male. Whereas in cardiac ICU admission for mechanical ventilation was male dominant (82%). The revenue from ventilators was calculated for each ICU. The revenue calculated showed that medical ICU had incurred the maximum revenue from ventilator utilization while burns ICU had incurred the least (Table I). The percent revenue incurred from each ICU also showed that medical ICU has contributed the maximum percentage of revenue nearly 53% towards revenue and burns ICU nearly 1%revenue from ventilator utilization.

The purchase cost for each ventilator was considered during calculation, ventilators purchase cost purchased before the year 2009 on an average was $11180, annual maintenance cost(AMC) and life of ventilator are considerednil but these are still in use. Seven ventilators were brought in the year 2009, 14 ventilators in the year 2010, 3 ventilators in the year 2011, two ventilators in the year 2012 and seven ventilators were brought in 2013. All the ventilators depreciation cost and AMC was calculated for the number of years it has been used in various ICUs (Table I).

On an average hospital pays $ 332 for oxygen to be used for ventilators only. It consumes $322 for electricity per month and very high manpower cost i.e. $2772 per month(Figure I) . Contribution margin represents the portion of sales revenue that is not consumed by variable costs and so contributes to the coverage of fixed costs.Contribution margin is the selling price per unit minus the variable cost per unit. The Contribution Margin Ratio is the percentage of contributionto total revenue, which is calculated from the total contribution to total revenue. Each ICU separate contribution Margin was calculated and found that the ICU 2 provides the highest contribution margin and Burns ICU with the least.

Total Revenue in all ICUs = $ 77736.206

Contribution Margin (CM) = Revenue – Variable cost = $ 54739.191

The Positive contribution margin ratio indicates that sales or revenue exceed the variable cost and expenses. In this hospital, we found nearly 70% of the sale or revenue is more than the variable cost and can contribute towards the fixed cost of the equipment.

Contribution Margin (CM) Ratio= (CM/Revenue) X 100 = 70.4%

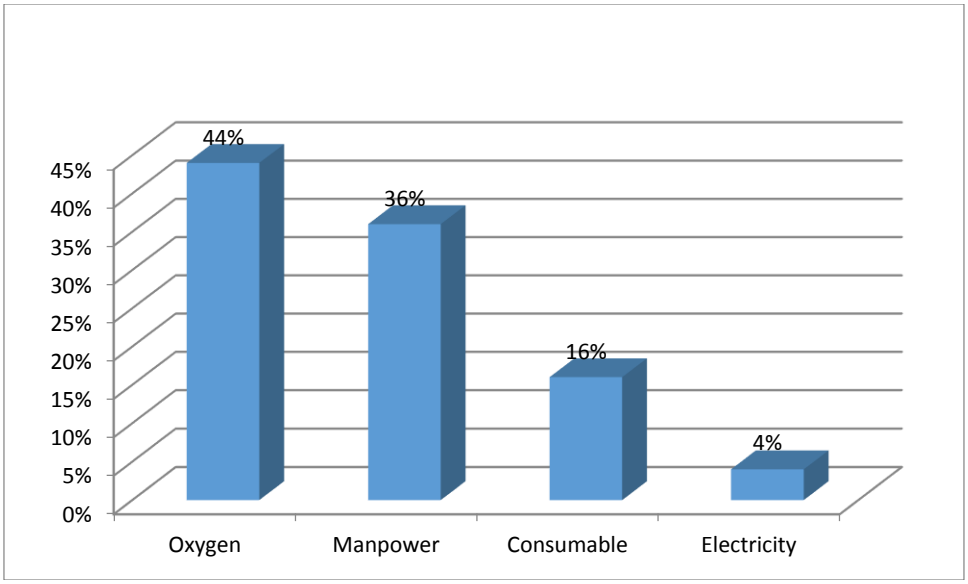
The monthly average fixed cost incurred by the hospital on ventilators was $ 245.4 that is irrespective of its utilization in adult ICUs. The total fixed cost in medical ICU was found to be maximum and the cardiac ICU the least.

Cost volume profit= Contribution Margin – Fixed Cost
= $34579 (Profit)

Table I. Demographic details, fixed cost, variable cost, revenue, utilization, and contribution margin associated with use of ventilators in each ICU

ICU Type		**Surgical ICU**	**Medical ICU**	**Casualty ICU**	**Cardiac ICU**	**Neurology ICU**	**Burns ICU**
Average length of stay		11±2	16±4	10±3	8±2	20±3	15±2
Gender (%)	M	68.1	64.2	65	81.8	72.7	38.5
	F	31.9	34.8	35	18.2	27.3	61.5
Payer (%)	Self	63.4	65.7	77.8	63.6	69.1	84.6
	TPA/Govt. schemes	36.6	34.3	22.2	36.4	30.9	15.4
Surgery(%)	Yes	37.8	12.6	0	18.9	50.9	15.6
	No	62.2	87.4	100	81.1	49.1	84.4
Total ICU days		990	3224	268	129	466	71
Total ventilator days		638	1953	217	38	370	15
Mean ventilator days		3.12±1.3	7.28±4	1.85±0.4	6.72±2.1	1.16±0.3	1.71±0.2
Available ventilator hours		27768	32040	14952	4272	10680	4272
Used ventilator hours		30410	35157	6747	1583	6350	528
Ventilation duration during ICU stay in %		64.44	60.58	80.97	29.46	79.40	21.13
Utilization rate (Overall)		1.095	0.566	0.451	0.3705	0.5945	0.1235
Oxygen consumption (in 1000 L)		18246	21094	4048.2	949.8	3810	316.8
Electricity cost by ventilator in USD		364.03	420.84	80.76	18.96	76.01	6.32
Manpower (Nurses Hours)		2534	2930	562	132	529	44
Ventilator kit charges in USD		3910	1990	1530	190	720	130
Ventilator purchase cost in USD		145534.3	178648.3	70889.71	43457.4	55955.88	19752.9
ACMC per year in USD		6112.441	7503.221	2977.368	1825.20	2350.147	829.617
Depreciation till date in USD		145534.3	122726	70889.71	43457.4	55955.88	15802.3
Total variable cost per ICU in USD		132	9260.88	2283.82	461.24	1831.79	183.25
Fixed cost of ventilator/year in in USD		6112.441	63425.53	2977.368	1825.20	2350.147	4780.20
Revenue by ventilator in USD		16769.12	39236.57	4730.22	1136.54	6950.221	443.529
Total revenue in USD		20679.12	41226.57	6260.221	1326.54	7670.221	573.529
Contribution margin in USD		11703.07	31965.69	3976.397	865.308	5838.441	390.279

Fig. 1: Variable cost associated with use of all ICUs ventilators



DISCUSSION

One of the importantcomponents of any resource allocation is a cost to procure and maintain such resources in organizations. As mechanical ventilators are high-costequipment certainly it includes its procurement cost, purchase cost, annual maintenance cost (AMC) and also the cost of human resources who are going to operate it. Calculation of costs in delivering mechanical ventilation can be divided into fixed and variable costs. Fixed costs to deliver mechanical ventilator in the ICU include salaries of caregivers, the purchase cost of mechanical ventilators, its maintenance cost and the maintenance required on the ICU[5]. Fixed cost is estimated to be nearly 80% of the cost involved in maintaining the equipment whereas only 20% of the cost is a variable cost[9]. Irrespective of the bed occupancy in ICU healthcare organization bears such fixed cost and tries to control only variable cost to decrease hospital costs, similar finding was reported bymany other researchers[10].Ventilators are critical equipment, which is used to save the life of a patient so required number should not be negotiated for the profit sake. In case the hospital bears such cost without optimal bed occupancy of near 70-80% in ICU, then it will increase its cost to the patient to overcome its debt and cost. Such economic crisis can lead to vicious cycle if not controlled or managed scientifically. As nearly, more than 40% of those admitted to an ICUeither borrow money or sell their assets to pay hospital bills[11].

The study shows that the utilization of ventilators in Burns ICU was the least and surgical ICU was the highest among all six ICUs. It is also required that the hospital should make some policy and look for the better utilization of ventilators to continue getting optimum profit. For optimum utilization of ventilators in ICUs, as cost containment strategy it would be ideal to have a common pool of equipment to share between ICUs. The pool should not have less than 2:1 ICU bed to ventilator ratio. The ICU director needs to periodically review the utilization pattern. Some of the ICU should exchange the ventilators as and when required from one ICU to another depending upon the requirement.

The distribution of ventilator to the number of beds always depends upon many factors like type of patients being admitted to that particular ICU. It was found that female admission to burns ICU was more as compared to male admission that can be a question leading towards the role of domestic violence or inappropriate cooking practices.

Strategies should be considered to ethically increase the number of ICU inpatients, optimize the resource utilization of ICUs. One strategy to increase the number of patients admitted to the ICU by increasing the number of patients referred from nearby hospitals and clinics. ICU Director of each ICU should be responsible for profits and losses of each ICU.

Combining activity-based costing with marginal costing, better plan and control the costs of health services can be obtained, ensuring that the organization's and countries goals are met. Burns ICU need more focus for the optimum utilization of ventilators and surgical ICU needs attention to have an optimum number of ventilators i.e.,1:1 ICU bed to ventilator ratio is required.

CONCLUSION

The ventilators are used in a manner that it is profitable to the organization although in initial years of any organization it may not be profitable but in long run, it is profitable to the hospital. The administrator should also focus that the ventilators are lifesaving critical equipment for the hospital's ICUs still its proper allocation and utilization will add further to the profit margin of the hospital.

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Author's Contribution: UR**:** conceptualized, collected data and formatted the write up of the article. NK: Guide to

UR, he did validating the data collection sheet, data collected, all permission required, conceptualization of the research paper and final editing of the article. AN: edited the article, did cost analysis and other statistical analysis and finally validating the results.

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