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Design of a Management Dashboard for the Intensive Care Unit: Determining Key Performance Indicators and their Required Capabilities

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Abstract

Introduction: Because the Intensive Care Unit (ICU) provides vital services to save the lives of critically ill patients, this unit has a special standing in health care systems; therefore it must be able to continuously monitor the quality of service and cost-effectiveness. The use of management dashboards can be helpful in real-time demonstration of essential information, problem recognition and performance improvement of the ICU. Therefore, this study aims to determine the key performance indicators for designing the management dashboard of an intensive care unit and identifying the required capabilities. *Material and Methods*: A total of 85 critical care experts participated in a two-round Delphi survey. An electronic questionnaire was utilized to gather data which include 50 Key Performance Indicators(KPIs) arranged in 3 main categories (structure, process and outcome). The relative importance of the KPIs and dashboard capabilities was determined using a five-point Likert scale. *Results*: The results of the study showed that a total of 28 indicators (13 KPIs in processes, 12 KPIs in output and 3 KPIs in structure) were identified. Also, the most important required capabilities of the dashboard for the intensive care unit included: simple graphic format, suitable chart, table and color, fit for a single screen, highlighted key point criteria, and user friendliness. *Conclusions*: In this study, ICU experts agreed on a set of 28 measurable KPIs for monitoring ICU performance. These sets of KPIs may be useful to assess performance appropriately in ICU departments of countries like Iran that do not have proper clinical information systems in hospitals. Also they suggest capabilities to effectively design ICU dashboards that could be used for all types of dashboards.

Keywords*:* Management dashboard; Intensive care unit (ICU); Key performance indicators; Capabilities

Introduction

Considering the complexity of patients' conditions and the extensive care services provided by an Intensive Care Unit (ICU), this is considered one of the vital units in a hospital [1, 2]. With the support of medical facilities and the clinical supervision of health service providers, such a unit provides 24-hour service for patients in need of life-saving care [3, 4]. Indeed, the ICU is a dynamic and complex environment which requires sensitive decisions [5]. Therefore, the provided care services should be based on predefined standards and there should be access to accurate and complete information [6].

The Society of Critical Care Medicine (SCCM) in the United States reports that more than 5.7 million patients are admitted to the ICU annually [7]. Mortality rates in the ICU are estimated to be 8 to 33 percent and also the admission cost in this unit is three times more than in other units [8-10]. Because ICU provides vital services to save the lives of critically ill patients, it must be able to continuously monitor the quality of service and cost-effectiveness [11, 12].

ICU performance was evaluated by analysis of clinical outcome indicators and utilization of resources such as: severity of illness scores, mortality, infection, length of stay, re-admission, and costs. There is an urgent need for managers and clinicians to get useful information in a timely manner to improve care quality and patient safety [13-15].

Nowadays, various tools and methods are available for accurate and continuous measurement of performance in different units of the organization, which can compare unit performance with predefined objectives and identify performance deviations. One of these tools is the management dashboard [9, 15]. In fact, the dashboard is a graphic screen used to offer updated, exact, and brief information for easy and understandable interpretation of organization performance. It is also a decision-making support tool able to perform root cause analysis of the problems, thus leading to higher effectiveness, efficiency, simple workflow, the opportunity to rapidly evaluate interventions and recognize performance flaws and mistakes [16-18]. Researchers have created dashboards for different health care departments, for example: emergency dashboard [19, 20], nursing dashboard [21,22], maternal care dashboard [23], operating room dashboard [24], laboratory dashboard [25], radiology dashboard [26, 27], or hospital infection control dashboard [17].

The results of theirs studies indicated that using dashboards leads to recognition of problems, improved quality performance, decreased medical errors, optimal management of resources, increase in the cooperation level of various care providers, empowerment of users, decrease in costs and reduction of data redundancy [17,18,28-30].

The accurate determination of a Key Performance Indicator (KPI) is considered one of the main necessities in designing management dashboards, which have to be developed according to the needs and objectives of the organization in order to offer valid and reliable measurements for an on-time assessment of performance based on determined standards [28, 29, 31]. The specified KPI should have characteristics such as: being special, measurable, accessible, realistic and timely [32-34]. Offering practical and strategic information in the form of key indicators of performance can assist managers in making intelligent and desirable decisions in organizational issues [30, 35].

Considering the importance of ICU in delivering critical care services to patients, the need to monitor the performance of this unit is important. As management dashboards provide the necessary capacity for real-time demonstration of essential information for management and clinical decision-making, their application can play an assisting role in problem recognition and performance improvement of the ICU. Therefore, this study aimed to determine key performance indicators for designing the management dashboard of an intensive care unit and also to identify their required capabilities.

Material and Method

This research is a descriptive cross-sectional study conducted in 2018. The research population includes all the critical care experts working in ICUs of the Educational and Therapeutic Centers of Medical Universities in Iran. Non-random purposeful sampling was used to select 85 participants

from the mentioned population. The key performance indicators of the ICU were extracted by reviewing scientific resources and documents.

The set of indicators in the Delphi technique was given to the experts in order to determine the relative importance of the suggested indicators on a five-point Likert scale (1=unimportant, 5=very important). An electronic questionnaire was utilized to gather data. The first section of the questionnaire contains demographic information on the participants including gender, age, work experience, and institutional affiliation. The second section of the questionnaire, according to the Donabedian model, indicators were classified into three main categories: structures, process and outcome. The last section of the questionnaire assesses the required capacities of the dashboard. The indicators that achieved a mean of more than 3 were added to the final list of KPIs.

Results

In order to achieve the objectives of the study and have access to a set of quality indicators, the selection process was conducted in three stages and a total of 28 indicators were selected. (Figure 1)

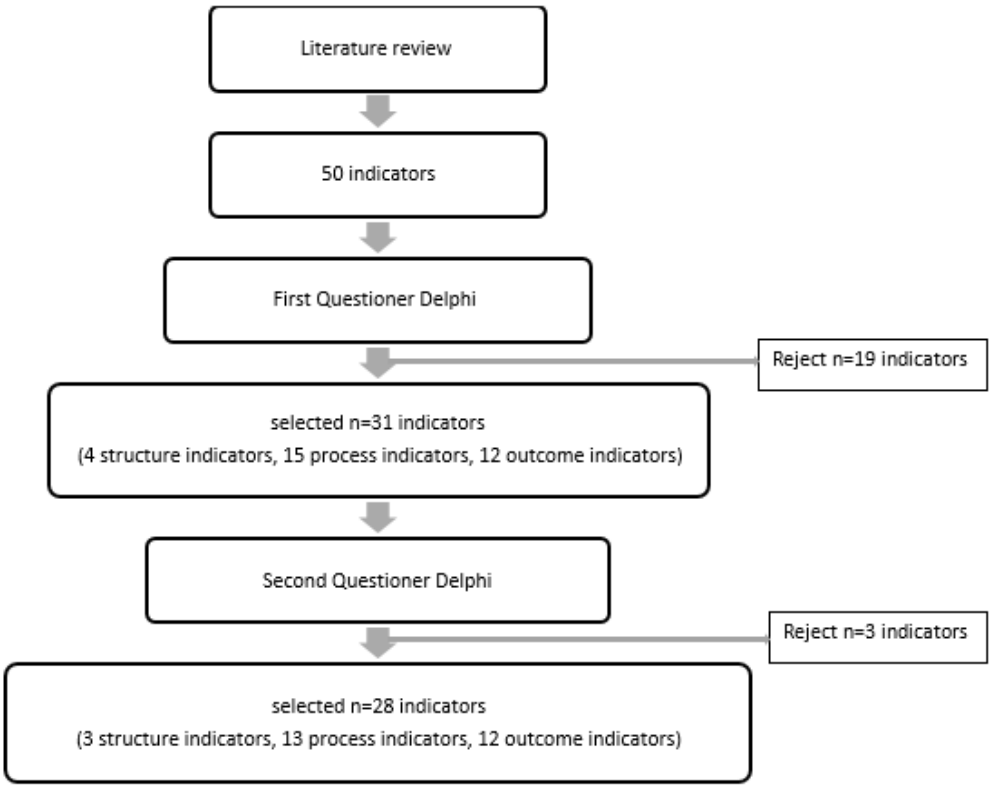

Figure 1. process of selecting KPIs for the management dashboard of the ICU

The list of indicators extracted from literature included 50 items (Table 1). This set of indicators was sent to 85 experts in ICUs all over the country through an electronic questionnaire. 60 completed questionnaires (70.59%) were returned. 58.33% of respondents (n=35) were men while 41.67% (n=25) were women and their mean age and work experience were 43.30±9.44 years and 10.30±4.23 years, respectively.

Table 1. List of KPIs in the ICU dashboard extracted from the review of the scientific literature

Key performance indicator	**Category**	**Author**
Duration of mechanical ventilation	Process, Outcome	De Vos et al. [35], Flaatten [30], Kastrup et al. [36], Kastrup et al. [37], Berenholtz et al. [38], Brown et al. [39]
Stress ulcer prophylaxis	Process	Whittle and] Berenholtz et al. [38] Shelton [33], Brown et al. [39]
TV (Tidal volume)	Process	Kastrup et al [36]
RASS (Goal Richmond agitation – sedation score)	Process	Kastrup et al. [36], Kastrup et al. [37]
BPS (Behavioral pain scale)	Process outcome	Berenholtz et al. [38], Kastrup et al. [36],] Kastrup et al. [37
VAS/NRS (Visual analog scale / numerical rating scale)	Process	Kastrup et al. [36], Kastrup et al. [37]
MAP (Mean arterial pressure)	Process	Kastrup et al. [36]
PIP (Peak Inspiration Pressure)	Process	Kastrup et al. [36]
Blood glucose	Process	Maartje et al. [26] , Kastrup et al. [36]
SOFA (Sequential organ failure assessment)	Process	Kastrup M [36], Kastrup M [37]
APACHE II (Acute Physiology And Chronic Health Evaluation II)	Process	Kastrup et al. [37]
SAPS II (Simplified Acute Physiology Score)	Process	Kastrup et al. [37], Kastrup et al. [36]
TISS (Therapeutic Intervention Scoring System)	Process	Kastrup et al. [37], Kastrup et al. [36]
Therapeutic hypothermia	Process, structure	Braun et al. [40], Flaatten [30]
DVT / VTE (Deep vein thrombosis/ venous thromboembolism) prophylaxis	Process	Whittle and Shelton [33], Brown et al.] [39
Monitoring of sedation analgesia	Process, Structure	Flaatten [30] , Braun et al. [40]
Severe sepsis	Structure or process	Braun et al. [40]
Appropriate early enteral nutrition	Process, structure	Flaatten [30], Braun et al. [40], Whittle] and Shelton[33
Hand hygiene	Process ,Outcome	Flaatten [30], Braun et al. [40], Whittle] and Shelton [33
End of life care pathway	Process	Whittle and Shelton [33], Flaatten [30]
Upper body elevation	Process	Braun et al. [40], Flaatten [30]
Number of inter clinical transport	Outcome, Process	Flaatten [30], De Vos et al. [35]
ICU beds occupied	Process, Structure, Outcome	De Vos M et al. [35] , Dantanarayana and Sahama [41] ,Whittle and Shelton [33], Rhodes et al. [44], Flaatten [30], Li and Benton [43]
Family/ patient satisfaction	Outcome, Structure, Human resource	Berenholtz et al. [38], De Vos et al. [35], [Flaatten [30], Ray et al. [42
Medication errors	Structure, Patient safety	De Vos et al. [35] , Ray et al. [42]
Number of refused admissions	Structure	Li and Benton [43]
Rate of delayed discharge	Access measure	Berenholtz et al. [38]
Canceled operating room	Access measure	Berenholtz et al. [38]

Key performance indicator	Category	Author
Multidisciplinary ward round	Structure, Process, Access measure	Whittle and Shelton [33], Rhodes et al.] [44], De Vos et al. [35
Intensivist cover 24/7	Structure	Shahama et al. [32], Flaatten [30], De Vos et al. [35], Braun et al. [40], Whittle snd Shelton [33], Rhodes et al. [44]
Nurse to patient ratio	Structure	De Vos et al. [35], Flaatten [30], Whittle] and Shelton [33
Rehabilitation	Structure	Whittle and Shelton [33]
Daily goal sheet	Structure, Process	Whittle and Shelton [33], Flaatten [30]
Rate of Mortality	Outcome	Berenholtz et al. [38], Dantanarayana and Sahama [41], Kastrup et al. [36], Brown et al. [39], Kastrup et al. [37], Rhodes et al. [44], De Vos et al. [35], Flaatten [30], Ray et al. [42], Whittle and Shelton [33]
Rate of length of stay	Process, Outcome, Structure	Berenholtz et al. [38], De Vos et al. [35], Kastrup et al. [36], Flaatten [30], Dantanarayana and Sahama [41], Ray et Whittle and Shalton [33],]al. [42], Brown et al. [39
Rate of readmission	Outcome, Structure, Process	Whittle and Shelton [33], Brown et al. [39], Rhodes et al. [44], Berenholtz et al. [38], Dantanarayana and Sahama [41], De Vos et al. [35], Flaatten [30], Ray et al. [42], Brown et al. [39], Dantanarayana and Sahama [41]
Rate of infection	Complication, Outcome, Infection-safety	Berenholtz et al. [38], Whittle Ans Shalton [33], De Vos et al. [35], Ray et al. [42], Rhodes et al. [44]
Post ICU discharge adverse event	Outcome, Structure, Patient safety, Adverse event indicator	Brown et al. [39], Rhodes et al. [44], Ray [30]et al. [42], Flaatten
Number of night discharges	Outcome	Whittle and Shalton [33], Flaatten [30]
Number of discharges	Outcome, Patient safety	Brown et al. [39], Ray et al. [42]
Number of unplanned extubation	Outcome	De Vos et al. [35], Rhodes et al. [44],] Flaatten [30
Incidence of decubitus ulcers	Outcome, Adverse event indicator	De Vos et al. [35] , Flaatten [30]
Patient fall rate in ICU	Safety and morbidity	Ray et al. [42]
Pressure sore rate	Outcome	De Vos et al. [35]
Needle stick rate	Safety health care worker	Ray et al. [42]
ICU Complication	Adverse event indicator, Outcome, Infection- safety	Flaatten [30], Berenholtz et al. [38], [30], Ray et al. [42], Rhodes et]Flaatten al. [44], Brown et al. [39
Failure to rescue	Outcome	Brown et al. [39]
Non clinical transfer	Outcome	Whittle and Shalton [33]
Economic	Outcome	Berenholtz et al. [38]
GCS (Glasgow Coma Scale) on admission	Process	Woldhek et al. [45]

At the end of the second round of Delphi, 28 indicators from 3 distinct categories were identified for the ICU dashboard. (Figure 2).

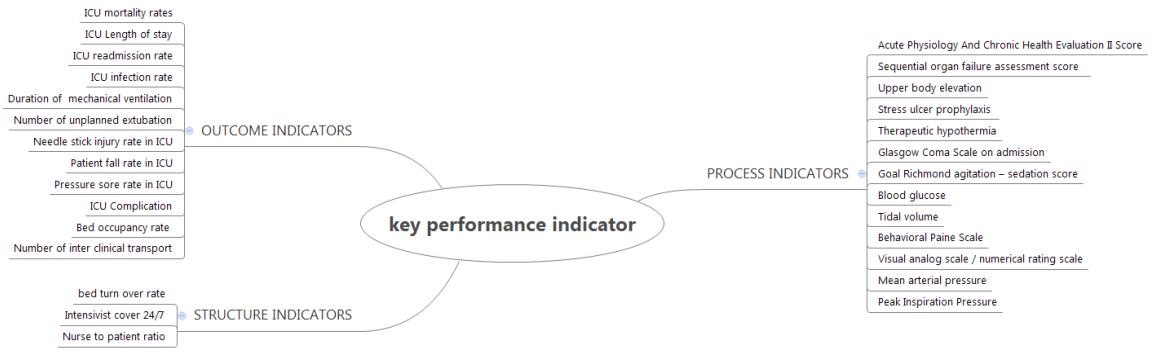

Figure 2. Final list of KPIs in the ICU dashboard

According to the experts' opinion, the most important required capacities of the ICU dashboard include: simple graphic format, suitable chart, table and color, fit for a single screen, highlighted key point criteria and user friendliness (Table 2).

Table 2. The capabilities required for designing the ICU dashboard (range 1-5)

Dashboard capability	Mean±SD
Simple and useful graphic format	4.87±0.35
Fits on a single screen	4.65±0.47
Able to navigate to a different layer of data granularity	4.18±0.88
Suitable chart, table, and color	4.72±0.43
Real time monitoring	4.36±0.73
Data base integration	4.12±0.91
User interaction with dashboard	4.23±0.82
Provides notification and warning	4.61±0.56
Guideline of use	4.08±0.97
Easy to use	4.52±0.62
User-friendly and attractive	4.47±0.69
User customization	4.38±0.74
Displays information based on user needs	4.35±0.79
Highlights key point criteria (out of threshold)	4.44±0.71
Able to perform analysis	4.23±0.86

Discussion

The study aimed to establish an agreement between experts in order to collect a set of suitable KPIs for assessing ICU performance. Two-round Delphi was used in order to achieve an agreement between experts. This method is widely used for real-world knowledge convergence between the experts in a field [46].

Most research conducted in order to determine KPIs has used the Donabedian model: structure, process and outcome [30, 33, 35, 36, 41, 44, 47]. This model was also applied in this study because it is flexible enough for use in diverse dashboards. In other cases, Flaatten H has also used another one called adverse event indicator [30]. Berenholtz SM et al used a quadruple structure (complication, access measure, process, and outcome) in their research to determine KPIs in the ICU [38].

By the end of two rounds of Delphi, the results of our study showed that 46.4 % (13 KPIs) of the accepted indicators were process indicators. Process indicators are the health care activities which include diagnosis, treatment, prevention, follow-up, etc. These indicators are accessible, practical and flexible, therefore quality improvement usually focuses on them [30, 35, 48].

The second sets of indicators were outcome indicators that represented 42.8 % (12 KPIs) of all accepted indicators. The outcome indicators usually assess the effect of care on the patient and describe the changes (wanted or unwanted) in the patients, which include readmission, mortality, length of stay, complication, infection, etc. [30, 35, 48].
Finally, 10.8 % (3 KPIs) of the agreed on KPIs were structure indicators. These indicators refer to aspects before patients' arrival. These almost constant properties include facilities, types of equipment, human resources and organizational features such as 24-hour physician presence, nurse-patient ratio, bed rotation [30, 35, 48].

Dantanarayana and Sahama conducted research at Queensland University to determine the main indicators in the ICU. The most important indicators included: ICU mortality rate, length of stay, bed occupancy rate, visit rate/ availability of intensivist, average number of readmission rate, rate of unplanned ICU readmission [41]. All of these indicators existed in our final list.

In the Netherlands, De Vos M acquired 12 indicators using the Donabedian model, after 3 stages of Delphi [35]. Our findings were in line with most of the indicators, except for two (patient satisfaction, and prevention of medication errors), which weren't selected by the experts in the first stage of Delphi, possibly due to lack of integrated electronic prescribing (ePrescribing) systems and no systematic patient tracking after discharge in Iranian hospitals. Kastrup M et al conducted research to determine a valid set of ICU indicators. The determined indicators were as follows: TISS, SAPSII, SOFA, RASS, NRS, BPS, APACHEII, mortality rate, duration of stay and duration of ventilator support. Most of these indicators were approved in our study [36, 37]. Two indicators (TISS & SAPSII) were eliminated from the list by clinical specialists due to their lack of assessment in therapeutic systems in Iranian hospitals.

The results of a study by the European Society of Intensive Care Medicine found 9 ICU indicators under output, structure, and process categories [44]. Our findings matched four of the European society indicators (unplanned extubation rate, readmission rate, infection rate, 24h availability), but indicators such as: adverse event reporting system, standardized handover procedure for discharging patient, reporting and analysis of SMR etc. were not included in the final list of our study, which could be due to the lack of clinical information systems and incomplete documentation of medical records by doctors.

According to the specialists surveyed in this study, the most important required capabilities of the dashboard for the intensive care unit include: simple graphic format, suitable chart, table and color, fit for a single screen, highlighted key point criteria and user friendliness, which are in line with a study by Buttigieg (monitoring, analysis, alert, color coding) [18]. In addition, Adams and Trisha refers to features of color coding, being specific and timely besides using alerts, ease of application and understanding information [17].

Ghazisaeidi et al. also consider alerts, drill down, and being timely as the capacities of the dashboard [49], which are in line with the findings of our study.
The results of a study by Wanda Presthus and Ida Bergum demonstrate that the most important capacities of a dashboard include: viewing the main information at one glance, ease of application by user, user's capability to pay attention to required areas, stability and simplicity, proper user interface, appropriate use of colors, charts and alerts [50].

In their paper, Rocha, Sónia, et al. recommended that when designing a management dashboard, more attention must be paid to essential capabilities such as single page display, comparison between indicators and concept analysis, avoidance of too many details, choice of suitable chart, table and color for the data [16]. In our research, critical care professionals also made similar suggestions about dashboard capabilities.

Unfortunately, 29.41% of the experts didn't respond to questionnaires. This can be seen as a limitation of our study. The generalizability of the findings may be limited, as most of the agreed upon KPIs in this study are probably a reflection of the Delphi group priority in Iranian ICUs. However, the methodological framework of the current study and the agreed upon KPIs may be helpful for further research.

Conclusions

The focus of this paper is on the determining KPI and required capabilities of ICU dashboards. In this study, ICU experts agreed on a set of 28 measurable KPIs for monitoring ICU performance. These sets of KPIs may be useful as metrics that are used to assess performance appropriately in ICU departments of countries like Iran that do not have proper clinical information systems in hospitals. However, updating KPIs should be done continuously according to new needs and organizational strategies. Also in this study experts suggest that in order to effectively design ICU dashboards, capabilities such as the simple graphic format, structure of suitable icons, user friendliness and fit on a single screen are required. These capabilities could be used for all types of dashboards.

List of abbreviations

ICU= intensive care unit
GCS= Glasgow coma scale
RASS= Goal Richmond agitation – sedation scale
BPS= Behavioral pain scale
VAS/NRS= Visual analog scale / numerical rating scale
MAP= mean arterial pressure
PIP= Peak Inspiration Pressure
SOFA= Sequential organ failure assessment
APACHII= Acute Physiology and Chronic Health Evaluation II
TV= Tidal volume

Ethical Issues

The study was approved by the Ethics Committee and Research Council of Urmia University of Medical Sciences (Ethical cod# ir.umsu.rec.1396.351).

Conflict of Interest

The authors declare that they have no conflict of interest

Authors' Contributions

MJ, MAVH and SS contributed in study design, data gathering, interpreting the results and drafting the manuscript. BR contributed in study design, interpreting the results and drafting the manuscript. ALL the authors read and approved the final manuscript.

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