

Clinical performance and resource utilization in the start of a totally new intensive care unit: Same staff, new area

Rendimiento clínico y uso de recursos en el arranque de una totalmente nueva unidad de cuidados intensivos. Mismo personal, nueva área

Pablo Álvarez-Maldonado^{1*}, Grisel Hernández-Ríos¹, Ulises Cerón-Díaz², Carlos Núñez-Pérez-Redondo¹, Francisco Navarro-Reynoso¹, and Raúl Cicero-Sabido^{1,3}

¹Department of Pulmonology and Thoracic Surgery, Hospital General de México Dr. Eduardo Liceaga; ²Intensive Therapy Unit, Hospital Español de México; ³Faculty of Medicine, Universidad Nacional Autónoma de México. Mexico City, Mexico

Abstract

Background: There is little information of intensive care unit (ICU) performance when it is relocated to a totally new and equipped area. **Objective:** The objective of this study was to analyze the clinical performance and use of resources of a new respiratory-ICU (nRICU) in a large third-level care hospital. **Methods:** This study was cross-sectional, comparative study using prospective data of patients admitted from July 17, 2017, to July 17, 2018. The Rapoport adjusted method was used to obtain the standardized clinical performance index (SCPI) and the standardized resource use index (SRUI). **Results:** Out of 354 patients, those who were readmissions or remained hospitalized and those whose treatment was withheld or withdrawn were excluded from the analysis. In 301 patients, the observed survival at hospital discharge was 63%, while the expected survival was 67.7%. Values of SCPI and SRUI were -1.03 and 0.05 , respectively, placing results in coordinates within two standard deviations when plotted in the Rapoport chart. There was a statistically significant difference in survival when comparing the study period with outcomes obtained in the RICU before its relocation (63% vs. 55%, $p = 0.01$). **Conclusions:** In its 1st year of operation, the nRICU had better clinical performance compared to the former RICU, with no change in the use of resources.

Keywords: Clinical performance. Use of resources. Intensive care unit.

Resumen

Antecedentes: Existe poca información acerca del desempeño de una unidad de cuidados intensivos (UCI) cuando es reubicada en un área totalmente nueva y equipada. **Objetivo:** Analizar el rendimiento clínico y el uso de recursos de la nueva UCI respiratoria (UCIR) de un hospital grande de tercer nivel. **Método:** Estudio transversal, comparativo, con datos prospectivos de pacientes ingresados del 17 de julio de 2017 al 17 de julio de 2018. Se usa el método ajustado de Rapoport para obtener el índice de rendimiento clínico estandarizado (IRCE) y el índice de uso de recursos estandarizado (IRURE). **Resultados:** De 354 pacientes fueron excluidos los reingresos, los pacientes aún hospitalizados y aquellos a quienes se limitó o retiró el tratamiento. En 301 pacientes la sobrevivencia hospitalaria fue del 63%, mientras que la sobrevivencia esperada fue del 67.7%. El IRCE fue -1.03 y el IRURE fue 0.05 , situando el resultado en coordenadas dentro de dos desviaciones estándar.

Correspondence:

*Pablo Álvarez-Maldonado

Dr. Balmis, 148

Col. Doctores

C.P. 06725, Ciudad de México, México

E-mail: pamyacs@yahoo.com

Date of reception: 26-06-2019

Date of acceptance: 23-07-2019

DOI: 10.24875/CIRUE.M20000136

Cir Cir (Eng). 2020;88(3):332-338

Contents available at PubMed

www.cirugiaycirujanos.com

2444-0507/© 2019 Academia Mexicana de Cirugía. Published by Permanyer. This is an open access article under the terms of the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

dar en el gráfico de Rapoport. Hubo una diferencia estadísticamente significativa en la sobrevivencia comparando el periodo de estudio con resultados de la UCIR obtenidos antes de su reubicación (63 vs. 55%, $p = 0.01$). **Conclusiones:** En su primer año de funcionamiento, la nueva UCIR tuvo mejor rendimiento clínico que la antigua, sin modificación en el uso de recursos.

Palabras clave: Rendimiento clínico. Uso de recursos. Unidad de cuidados intensivos.

Introduction

Among continuous efforts to improve the performance of the intensive care unit (ICU), having resources, and an adequate area for the care of critically ill patients can be considered the starting point. Multicenter analyses argue that excessive ICU expenditure is not necessarily associated with an exceptional clinical performance¹; however, addressing environment-specific factors to improve ICU performance in such a way that it impacts on patients is recommended^{2,3}. Little is known about changes in the performance of an ICU when relocated on an entirely new area with the same staff that makes it up. With a construction dating back to the early 1900s and equipment mostly not in compliance with current standards, the respiratory intensive care unit (RICU) of General Hospital of Mexico “Dr. Eduardo Liceaga” (first specialty hospital in the country) left its location in July 2017 to be relocated, along with the pulmonology and thoracic surgery department, in a completely new and equipped building within the hospital. This study analyzes the new RICU clinical performance and use of resources during its 1st year of operation, and compares the results with those obtained prior to its relocation.

Methods

Design

This study was cross-sectional, comparative, and retrospective study with prospectively-obtained data.

Patients and setting

Data of patients who were admitted from July 17, 2017, to July 17, 2018 to the new RICU of General Hospital of Mexico “Dr. Eduardo Liceaga”, a public teaching hospital of 1,131 beds, are included in the study. The new RICU is one of eight intensive care units within the hospital; it has 12 fully equipped beds and is in charge of a multidisciplinary team consisting of four certified intensivist doctors (distributed in

morning, evening, A nights [Monday, Wednesday and Friday] and weekend [8 am to 8 pm] shifts), four certified pulmonologist doctors distributed in different shifts as consultants and treating physicians in the absence of an intensivist on the shift, variable staff of intensivist, and non-intensivist nurses, with a nurse: patient ratio from 1:1 to 1:3 and intensivist nurse: patient from 1:3 to 1:6, three inhalotherapists (on morning, evening, and weekend shifts), two rotating pulmonology residents (first and second years), and two to six internal medicine, medical emergencies, anesthesiology, critical medicine, and pulmonology specialties rotating residents per month, from the same hospital or from other hospitals. The multidisciplinary team of the new RICU is the same one that it had at its old building. Staff variations occurred before the transfer to the new building exclusively in the number of intensivists, with the hiring of one intensivist for the evening shift in September 2015, one for the a night shift in April 2016 and one more for the 8 am-8 pm weekend shift in January 2017.

Main structural, design, and equipment differences between the new and the old RICU

The new RICU is located in the new building for the care of cardiorespiratory and vascular diseases at General Hospital of Mexico, opened in July 2017 after a construction period of 3 years. It has an area of 530 m² with 12 fully insulated cubicles with glass sliding doors and walls, as well as windows facing the outside. Electricity, medical air, oxygen, and equipment outlets are installed on the posterior wall at patient headboard, and each cubicle has a washbasin. Among the equipment, each cubicle has a fully automatic hospital bed (Striker, InTouch®), a recliner (*reposit*), a monitor (Philips-IntelliVue® MX800) with cardiac output monitoring options by PiCCO® method, time capnography, bispectral index, pulse pressure variation, among others, and a mechanical ventilator with the capacity to provide invasive and non-invasive ventilation (Puritan-Bennett™ 840). Its design has an entrance with washbasin as a transfer area for

health personnel and another for family members, and an access door exclusive for patients on stretcher. It also has a rest area for doctors and an administrative office within the same unit. The entire space has air conditioning, air injector, and extractor. In addition, for sending and receiving biological samples and medicines, there is a pneumatic system that communicates with different areas within the building.

The RICU of the old building was located in an area adapted for its use dating from the early 1900s, originally intended for the care of tuberculosis patients. It had seven non-automatic beds separated by curtains of synthetic material, with a total area of 146 m², a single access door for patients, relatives, and health personnel, which also served as access for ventilation (air inlet), a washbasin at the entrance of the unit, a sink in the center of the unit, a bathroom for the disposal of organic fluids, and an equipment consisting of Spacelabs® mCare-300 monitors at each bed with invasive pressure visualization option and Viasys™ Avea® mechanical ventilators for invasive ventilation, acquired in 2009 during the influenza A H1N1 pandemic. It did not have a rest area for doctors or an administrative area, and only had two armchairs (*repose*) for common use by hospitalized patients.

Blood gases processing and portable X-ray acquisition with equipment available *in situ* are features of both the old and the new RICU.

Data collection and statistical analysis

Data were prospectively collected from the DeDUCIR⁴ database, which has demographic, severity, prognostic, and hospital and ICU length of stay times information, among others. Two RICU doctors are responsible for filling out the database on a daily basis. In addition, missing information on hospital discharge (date and patient status at discharge) was directly collected from the hospital internal electronic system. The patient characteristics are described using absolute values (percentages) for dichotomous variables, and mean $\pm$ standard deviation for continuous variables. In addition to calculating the proportion of alive patients observed and expected at hospital discharge, an analysis of clinical performance and resources use was carried out using Rapoport adjusted method. Detailed information on the tool and its interpretation are described below in the *Methods* section. For comparative analysis, data obtained from the former RICU for the March 1, 2010-March 1, 2015 period were used⁵, as well as unpublished results on clinical performance

and use of resources for the March 1, 2015-March 1, 2017 period. The patient characteristics were compared using Pearson's Chi-square test for dichotomous variables and Student's t-test for continuous variables. $p < 0.05$ indicated statistical significance. No patient data appear in this study, its development is planned in the periodic quality reports within the institution and did not require approval by the Institutional Ethics and Research Committees or informed consent for inclusion.

Revised Rapoport-Teres method

The revised Rapoport-Teres¹ method cross-tabulates clinical performance (standardized clinical performance index [SCPI]) and cost-effectiveness (standardized resource usage index [SRUI]) in a two-dimensional graph. The calculation of the indexes detailed below is the same that was used for clinical performance and resource usage analysis of the old RICU⁵.

- SCPI (x-axis): To obtain the standardized clinical performance index, the difference in survival (Δ survival) of the study population is first obtained by subtracting expected survival from observed survival as follows:

$$\Delta = (\text{current survival} - \text{expected survival}) \times 100$$

To express this information in standard deviation units (to standardize) of the mean of the reference ICUs that participated in the development of the Rapoport adjusted model, mean survival difference (0.110) is extracted from this difference and divided by the survival difference standard deviation (4.668) obtained from the Rapoport adjusted model, and the result is the x-axis value or SCPI. A positive value indicates that the difference between observed and expected survival of the ICU that is being evaluated is better than that of reference ICUs average, while a negative result indicates the opposite.

- SRUI (y-axis): To obtain the standardized resource usage index, a value is assigned to the days of ICU stay and to post-ICU days for each patient. The highest value is assigned to the first ICU day (four points), subsequent ICU days are assigned a value of 2.5 points per day, and post-ICU days one point per day. Average value of the scores obtained from all patients is called "weighted hospital days" (WHD). As in the survival analysis, it is necessary to have a weighted hospital days expected average value; for this,

Rapoport adjusted model provides an equation derived from a regression analysis that includes independent variables that were identified as predictors of average weighted stay for the evaluated ICU:

$\text{Log}_{10}(\text{WHD}) = 1.008 + 0.753 \times (\% \text{ of in-hospital deaths}) + 0.432 \times (\% \text{ of unscheduled surgery}) + 0.228 \times (\% \text{ of mechanical ventilation within 1 h of admission to the ICU}) - 0.708 \times (\% \text{ of patients discharged to post-acute care outside the hospital}).$

Subsequently, the difference between expected and current weighted hospital days is obtained:

$$\Delta\text{WHD} = \text{WHD} - \text{eWHD}$$

To standardize this result, as with survival, this difference is subtracted the ΔWHD average (-0.232) and divided by ΔWHD standard deviation (3.786), which were obtained from Rapoport adjusted model UCI group, and the result is the y-axis value or SRUI. A positive result indicates that fewer than expected resources were used, and a negative result indicates the opposite.

For visual interpretation, SCPI and SRUI values are plotted on a four-quadrant coordinate graph that allows the results to be compared with those obtained by IMPACT project participant units in the United States of America (in standard deviations), as well as a comparison of results between different periods in the same ICU. Coordinates in the north-east quadrant, that is, SCPI and SRUI values > 0, indicate better survival and lower resource usage, while negative values for these indexes indicate the opposite.

Results

In the study period, 354 patients were admitted to the new RICU. Re-admissions ($n = 27$), subjects older than 18 years ($n = 0$), patients who remained hospitalized at the time the analysis was carried out ($n = 11$), and those in whom treatment was limited or withdrawn ($n = 15$) were excluded from analysis. In 301 patients, observed hospital survival was 63%, while expected survival according to the SAPS-3 scale was 67.7%. Of total patients, 9.6% died within the first 48 h of RICU admission, while 5.3% died within the first 24 h. According to Rapoport adjusted method, SCPI was -1.03 (x-axis) and SRUI was 0.05 (y-axis), with the result being located in coordinates of the top left quadrant of the Rapoport graph, within two standard deviations (Fig. 1). Table 1 shows included patients characteristics and

Table 1. Patient characteristics in both periods

	Former RICU (5) 2010-2015 n = 1.136	New RICU 2015-2018 n = 301	p
Age, years, mean $\pm$ SD	48 $\pm$ 17	50 $\pm$ 15	0.06
Gender, males/females (%)	544 (48)	146 (48)	1.0
SAPS-3 $\pm$ SD	51 $\pm$ 19	55 $\pm$ 19	0.001
SOFA $\pm$ SD	5.2 $\pm$ 4.8	5.0 $\pm$ 4.7	0.5
Invasive mechanical ventilation, n (%)	704 (62)	178 (59)	0.34
Origin			
Pulmonology hospitalization area	321 (28.3)	58 (19.3)	58 (19.3)
Emergency department	247 (21.7)	65 (21.6)	65 (21.6)
Pulmonology operating room	241 (21.2)	95 (31.6)	95 (31.6)
Other hospitalization area	149 (13.1)	49 (16.3)	49 (16.3)
Other departments operating room	116 (10.2)	28 (9.3)	28 (9.3)
Another ICU	33 (2.9)	2 (0.7)	2 (0.7)
Pulmonology outpatient clinic	19 (1.7)	2 (0.7)	2 (0.7)
Another hospital	10 (0.9)	2 (0.7)	2 (0.7)
Reason for ICU admission			
Respiratory failure	523 (46.0)	153 (50.8)	0.13
Post-operative surveillance	375 (33.0)	69 (22.9)	< 0.001
Cardiovascular failure	180 (15.8)	60 (19.9)	0.08
Neurological failure	38 (3.3)	5 (1.7)	0.14
Kidney failure	13 (1.1)	6 (2.0)	0.2
Metabolic failure	5 (0.4)	3 (1.0)	0.2
Hematological failure	1 (0.1)	3 (1.0)	-
Liver failure	1 (0.1)	2 (0.7)	-
Hospital survival (%)	55	63	0.01

SD: standard deviation; SAPS-3: Simplified Acute Physiology Score 3; SOFA: Sequential Organ Failure Assessment; RICU: respiratory intensive care unit.

their comparison with the population of the 2010-2015 previous analysis. In addition, with the available data, the comparison of indexes and their variables is shown including an additional period (March 1, 2015-March 1, 2017) before the RICU relocation. A statistically significant difference in survival was observed between performance analysis periods comparing the new RICU period of activity with that of the old one for the years 2010-2015 (63 vs. 55%; $p = 0.01$), as well as a trend to a better survival when comparing the period of activity of the new RICU with that of the old one for the years 2015-2017 (63 vs. 56%; $p = 0.056$). There was an average of 25 patients treated per month in the new RICU (Table 2), in comparison with 19 patients treated per month in the two periods before its relocation.

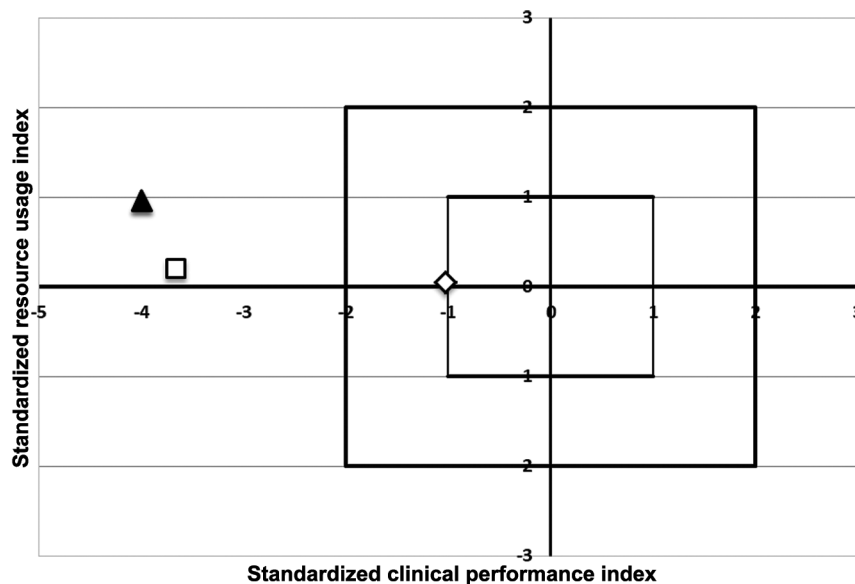


Figure 1. Adjusted Rapoport method graph for intensive care units (ICU) graduated in standard deviations (SD). Coordinates within ± 2 SD indicate that the performance of an ICU is consistent with that of its peers, units of the IMPACT project considered “standard” against which it is compared. The triangle and square indicate coordinates of performance and resource usage of the old RICU in the 2010-2015 and 2015-2017 periods, respectively; the diamond indicates coordinates of performance and resource usage of the new RICU (2017-2018).

Discussion

Some of the expected benefits of measuring the performance of an ICU include the possibility of comparing the results with those of other ICUs regarded as standard (benchmarking) and making comparisons for the same unit at different periods. Furthermore, given that an ICU can generate up to one-third of a hospital expenditure, performance and cost-effectiveness assessment is of paramount importance for the management of its resources, with numerous tools being available for this purpose⁶⁻⁸. In 1994, Rapoport et al.⁹ proposed a two-dimensional model that cross-tabulates clinical performance and resource usage using relatively easy-to-obtain information and a coordinate graph for practical visual interpretation of results. Clinical performance is attributed to the survival obtained at hospital discharge, while resource usage is mainly based on each patient hospital stay time inside and outside the ICU, with a specific value being assigned to each period based on the degree of interventions it generates (plus points for the first day in the ICU). In 2007, the method underwent calibration¹ and currently continues to be used by ICUs of Project IMPACT in the United States of America and by some Mexican ICUs as an indicator of results. In our ICU, the DeDUCIR computed database (which has its backgrounds in the BASUTI local database)¹⁰

Table 2. Variables for SCPI and SRUI calculation at different periods and results by period

Period	2010-2015 ⁵	2015-2017	2017-2018*
Patients included for the calculation	1136	453	301
Actual survival	0,55	0,56	0,63
Survival expected by SAPS-3	0,74	0,73	0,67
Survival difference	-18,56	-16,7	-4,7
SCPI (x-axis)	-4	-3,67	-1,03
Unscheduled surgery (%)	0,14	0,1	0,11
Mechanical ventilation (%)	0,62	0,56	0,57
Discharge to external acute care (%)	0,01	0	0,01
Weighted hospital days	30,14	31,81	28,69
Predicted weighted hospital days	33,92	32,37	28,64
Difference in hospital days	3,78	0,56	-0,05
SRUI (y-axis)	0,94	0,21	0,05

SCPI: standardized clinical performance index; SRUI: standardized resource utilization index; SAPS-3: Simplified Acute Physiology Score-3.

*New respiratory intensive care unit.

has allowed, since its implementation in 2010, to perform this type of analysis as well as other projects linked to quality improvement.

From an organizational point of view, the components of an ICU dedicated to the care of a particular patient, including not only supplies (materials) but also the physical area, equipment and health personnel, can be referred to as “resources.” If these components are limited, clinical performance is expected to be deficient^{2,3,11}. In the particular case of the RICU, before its relocation, a trend toward better clinical performance was observed when there was higher use of resources (days of stay/patient)⁵, which allowed identifying areas of opportunity, such as the need for intensivist physicians for an assistance coverage of 24-h a day, 7 days a week. The work carried out in the 2 years before its relocation allowed to achieve for one-third of the necessary staff to be covered by certified intensivists; however, the lack of intensivists remains one of its main limitations, which if corrected could lead to better clinical outcomes¹². The movement to a new physical area with design and equipment adapted to current standards allowed the RICU to match model units in terms of structure and gave way to a fresh and motivated start of activities by its staff.

Although there is no information about the performance of an ICU when starting operations with already known health personnel with experience in many of its processes, performance is expected to lean toward better outcomes; however, investment in structure and equipment can eventually lead to even greater expenditure on patients with poor prognosis, which is linked to the delivery of futile advanced care and longer stay, which has been called escalation of commitment in the ICU¹³. Although patients of the new RICU were more seriously ill and there were 31% more of patients cared for per month in comparison with the old RICU, their survival was closer to that expected by the SAPS-3 predictive model, with the difference being statistically significant with regard to the 2010-2015 period. Other factors not analyzed in this report may in some way have influenced the better survival observed in the new RICU. Several quality improvement projects were implemented since 2010 in the old RICU^{4,14,15}, whose maturation may have led to an increasingly higher impact over the years, which would explain that in the period immediately before relocation (2015-2017); the survival difference already showed a trend toward better results. On the other hand, the new RICU had a larger number of patients coming from the operating room than the old one, not necessarily for post-operative surveillance but with acute conditions and

presence of failure in one or more vital organs, in whom we have observed an association with a benign behavior and better outcomes in comparison with serious medical conditions and even emergency surgeries involving other organ systems^{16,17}. In addition, ICU environmental contamination by prevalent pathogenic microorganisms (such as *Pseudomonas aureuginosa* and *Acinetobacter baumannii*), which plays a major role in the development of nosocomial infections¹⁸ and that is linked to increased morbidity and mortality, ceased to pose a risk at the start of activities of the new RICU, given that the patients of the old one were treated until discharge or relocated to other ICUs within the hospital before starting activities in the new building.

There are some limitations, already commented in the clinical performance and resource usage of the former RICU analysis⁵, which are repeated for the present analysis: (1) for SCPI and SRUI calculation, expected survival was used in accordance with the SAPS-3 mortality predictive model and not with MPM-II₀ predictive model, by means of which the tool was validated; (2) given that the proportion of patients who required mechanical ventilation within the 1st h of RICU admission was not available, the entire proportion of patients on mechanical ventilation was used for SRUI calculation (this aspect makes for its value to be rather underestimated); and (3) a new recalibration of the Rapoport method may be necessary in order for it to adjust to more contemporary clinical results and resource utilization, which are influenced by technological and pharmaceutical advances, as well as by new scientific evidence, among others^{19,20}. However, since the comparison between periods is the main reason for the analysis, and having used the same methodology for the three periods that are compared, we believe that although modifications in the method limit generalization, they do not have a significant impact on the comparative analysis that is presented.

Conclusions

In its 1st year of activities, the new RICU had a better clinical performance than the old one, without an important modification in the use of its resources. There is an association of the RICU improvements in physical structure and equipment and a progression to a performance that is comparable to that of other ICUs considered standard in the world.

Conflicts of interests

The authors declare that they have no conflicts of interest or having received any funding related to the preparation of this work. Its performance adheres to the ethical requirements of the institution, where it was developed.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments have been performed on humans or animals for this research.

Confidentiality of data. The authors declare that no patient data appear in this article.

Right to privacy and informed consent. The authors have obtained informed consent from the patients and/or subjects referred to in the article. This document is in the possession of the corresponding author.

References

- Nathanson BH, Higgins TL, Teres D, Copes WS, Kramer A, Stark M. A revised method to assess intensive care unit clinical performance and resource utilization. *Crit Care Med*. 2007;35:1853-62.
- Schultz MJ, Dunser MW, Dondorp AM, Adhikari NK, Iyer S, Kwizera A, et al. Current challenges in the management of sepsis in ICUs in resource-poor settings and suggestions for the future. *Intensive Care Med*. 2017;43:612-24.
- Geiling J, Burkle FM Jr, Amundson D, Dominguez-Cherit G, Gomersall CD, Lim ML, et al. Resource-poor settings: infrastructure and capacity building: care of the critically ill and injured during pandemics and disasters: CHEST consensus statement. *Chest*. 2014;146(4 Suppl):e156S-67S.
- Álvarez-Maldonado P, Cueto-Robledo G, Cerón-Díaz U, Pérez-Rosales A, Navarro-Reynoso F, Cicero-Sabido R. Indicadores de calidad en una unidad de cuidados intensivos respiratorios. *Análisis inicial de la base de datos DEDUCIR*. *Med Intensiva*. 2012;36:518-20.
- Álvarez-Maldonado P, Pérez-Rosales A, Cueto-Robledo G, Cerón-Díaz U, Núñez-Pérez-Redondo C, Navarro-Reynoso F, et al. Clinical performance and resource use of a respiratory intensive care unit. Analysis of five years of clinical activity. *Rev Med Hosp Gen Mex*. 2016;79:144-9.
- Elguea Echavarría PA, Cerón Díaz UW, Esponda Prado JG, Cabrera Jardines R. Calidad y costo-efectividad en la atención del paciente crítico. *Rev Asoc Mex Med Crit Ter Int*. 2012;26:42-50.
- Villagómez Ortiz AJ. Costo efectividad de la atención en cuidados intensivos. *Rev Asoc Mex Med Crit Ter Int*. 2012;4:192-3.
- Timmers TK, Verhofstad MH, Moons KG, Leenen LP. Intensive care performance: how should we monitor performance in the future? *World J Crit Care Med*. 2014;3:74-9.
- Rapoport J, Teres D, Lemeshow S, Gehlbach S. A method for assessing the clinical performance and cost-effectiveness of intensive care units: a multicenter inception cohort study. *Crit Care Med*. 1994;22:1385-91.
- Cerón U, Sierra A, Martínez R, Vázquez JP. Base de datos para el control de calidad y utilización de recursos en la unidad de terapia intensiva. *Rev Mex Med Crit Ter Int*. 1996;10:105-201.
- Dat VQ, Long NT, Giang KB, Diep PB, Giang TH, Diaz JV. Healthcare infrastructure capacity to respond to severe acute respiratory infection (SARI) and sepsis in Vietnam: a low-middle income country. *J Crit Care*. 2017;42:109-15.
- Neuraz A, Guérin C, Payet C, Polazzi S, Aubrun F, Daillier F, et al. Patient mortality is associated with staff resources and workload in the ICU: a multicenter observational study. *Crit Care Med*. 2015;43:1587-94.
- Braxton CC, Robinson CN, Awad SS. Escalation of commitment in the surgical ICU. *Crit Care Med*. 2017;45:e433-e436.
- Álvarez-Maldonado P, Cueto-Robledo G, Cicero-Sabido R. Changes observed in three quality indicators after the implementation of improvement strategies in the respiratory-ICU. *Med Intensiva*. 2015;39:142-8.
- Álvarez-Maldonado P, Reding-Bernal A, Hernández-Solís A, Cicero-Sabido R. Impact of strategic planning, organizational culture imprint and care bundles to reduce adverse events in the ICU. *Int J Qual Health Care*. 2019;31:480-4.
- Fernández MA, de la Escosura G, Cicero R. Valoración de APACHE II. Experiencia en dos grupos con patología neumológica. *Rev Inst Nal Enf Resp Mex*. 1996;3:187-93.
- Álvarez-Maldonado P, Pérez-Rosales A, Núñez-Pérez Redondo C, Navarro-Reynoso F, Cicero-Sabido R. Cirugía de urgencia torácica versus no torácica. Resultados en una unidad de cuidados intensivos respiratorios. *Rev Asoc Mex Med Crit Ter Int*. 2015;19:133-7.
- Rusotto V, Cortegiani A, Fasciana T, Iozzo P, Raineri SM, Gregoretti C, et al. What healthcare workers should know about environmental bacterial contamination in the intensive care unit. *Biomed Res Int*. 2017;2017:6905450.
- Abascal Caloca C, Cerón Díaz UW, Vázquez Mathieu JP, Sierra Unzueta A. Análisis de costo-efectividad por el método de Rapoport en un año de actividad asistencial en una unidad de terapia intensiva polivalente privada en México. *Rev Asoc Mex Med Crit Ter Int*. 2006;1:5-11.
- Cerón Díaz UW, Abascal C, Sierra Unzueta A. Comparación del rendimiento clínico y costo-efectividad en tres periodos durante nueve años de actividad asistencial de una unidad de terapia intensiva. *Rev Asoc Mex Med Crit Ter Int*. 2006;20:126-35.