Analysis of physical function, muscle strength and pulmonary function in surgical cancer patients: a prospective cohort study.

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Abstract

The aim of this study was to investigate mobility, physical functioning, peripheral muscle strength, inspiratory muscle strength and pulmonary function in surgical cancer patients admitted to an intensive care unit (ICU). We conducted a prospective cohort study with 85 patients. Mobility, physical functioning, peripheral muscle strength, inspiratory muscle strength, and pulmonary function were assessed using the following tests: ICU Mobility Scale (IMS); Chelsea Critical Care Physical Assessment (CPAx); handgrip strength and Medical Research Council Sum-Score (MRC-SS); maximal inspiratory pressure (MIP) and S-Index; and peak inspiratory flow, respectively. The assessments were undertaken at ICU admission and discharge. The data were analyzed using the Shapiro-Wilk and Wilcoxon tests and Spearman's correlation coefficient. Significant differences in inspiratory muscle strength, CPAx, grip strength, MRC-SS, MIP, S-Index, and peak inspiratory flow scores were observed between ICU admission and discharge. Grip strength showed a moderate correlation with MIP at admission and discharge. The findings also show a moderate correlation between S-Index scores and both MIP and peak inspiratory flow scores at admission and a strong correlation at discharge. Patients showed a gradual improvement in mobility, physical functioning, peripheral and inspiratory muscle strength and inspiratory flow during their stay in the ICU.

Introduction

Advances in cancer treatment have led to a considerable increase in survival, with studies reporting long-term survival rates after cancer surgery of almost 60%[1–3]. Nevertheless, cancer-related complications are common during the course of the disease. The most common reasons for admitting cancer patients to the intensive care unit (ICU) are risk of developing postoperative complications, disease progression or other non-cancer related factors[2–4].

There are many types of cancer treatment, each of which can involve multiple therapies[1, 5]. The type of treatment depends on the clinical assessment and type and stage of the cancer, with surgery being the most common method of tumor removal[5]. Surgery combined with chemotherapy, radiotherapy, hormonal therapy or immunotherapy is therefore common[6]. The effects of these treatments can include an increase in the activity of cytokines, leading to changes in muscle protein metabolism, increased protein degradation and decreased protein synthesis, ultimately resulting in a reduction in muscle strength. This in turn can lead to sarcopenia, cachexia and muscle fatigue, as well as a decline in functional capacity and quality of life[7].

Pre-existing health conditions, the stage of the cancer, type of malignancy, presence of neutropenia, and need for mechanical ventilation are also important factors that determine cancer patient outcomes[8].

Functional status has been shown to be an excellent prognostic marker for cancer patients, regardless of age and comorbidities, as functional decline is associated with poorer survival[8–10]. Functional status is negatively affected by immobilization after surgery, which can lead to a loss of muscle strength and reduced pulmonary function[8].

The early identification of functional status and muscle strength is therefore important for defining individualized preventive and curative measures aimed at improving patient health outcomes. The aim of this study was to investigate mobility, physical functioning, muscle strength and pulmonary function in surgical cancer patients admitted to the ICU.

Methods

TYPE OF STUDY

We conducted a prospective cohort study following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)[11] guidelines. The study was undertaken in a Surgical ICU in the Federal District Base Hospital between October 2020 and February 2021.

The study protocol was approved by the research ethics committees at the University of Brasilia (CAAE: 31665120.0.0000.8093) and Federal District Strategic Management Institute (CAAE: 31665120.0.3001.8153). All participants signed an informed consent form.

PARTICIPANTS

The study participants were recruited using convenience sampling, adopting the following inclusion criteria: patients of both sexes aged over 18 who had been in the ICU for more than 24 hours and were hemodynamically and neurologically stable and able to understand the proposed tests. The following individuals were excluded: hemodynamically unstable patients; pregnant women; patients with neurological and/or neuromotor impairments; patients who had undergone head and neck surgeries or thoracic surgeries involving diaphragm plication; patients with unstable bone fractures; patients who had been hospitalized in the last six months; and patients receiving palliative care.

ASSESSMENT PROTOCOL

The assessments were undertaken at ICU admission (24 hours after surgery) and discharge. The patients received physical therapy three times a day during their stay in the ICU in accordance with the ICU protocol.

The following data were collected on the patient’s first day in the ICU: clinical variables (APACHE II, SOFA score and SAPS II); surgical risk; surgery duration; duration of orotracheal intubation (OTI); type of anesthesia; and length of ICU stay. We also assessed mobility, physical functioning, peripheral muscle strength, respiratory muscle strength and pulmonary function.

The assessments were carried out by experienced physiotherapists who received prior training in how to use the scales and assessment tools. The physiotherapists explained the assessment beforehand so that the patient was able to perform the task as independently as possible.

Mobility was measured using the single-domain ICU Mobility Scale – IMS[12,13]. The scale is scored from 0 to 10, where 0 indicates no mobility (passively rolled or passively exercised by staff) and 10 indicates a high level of mobility (walking independently without a gait aid)[12]. The IMS has been translated into Portuguese and adapted for use in Brazil[13].

Physical functioning in ICU was assessed using the Chelsea Critical Care Physical Assessment (CPAx)[15], developed and validated by Corner et al. (2013; 2014)[15,16]. The CPAx measures key components of physical functioning (respiratory function, cough, moving within the bed, supine to sitting on the edge of the bed, dynamic sitting, standing balance, sit to stand, transferring from bed to chair, stepping and grip strength) and is the only physical functioning in ICU assessment tool that includes aspects of respiratory function. The tool consists of 10 physical function items ranging from complete dependence to independence. The score ranges from 0-50, where the higher the score the greater the level of independence[14]. The CPAx has been translated into Portuguese and adapted for use in Brazil[14].

Muscle strength was assessed according to grip strength (GS), which was measured using a hydraulic hand-held dynamometer (JAMAR®, Saehan Hydraulic Hand Dynamometer)[17]. GS was measured with patients sitting on a standard chair with feet flat on the floor and the elbow flexed at a 90º angle. When this was not possible, the participant was placed in a supine position with elbows supported on the bed at a 45º angle and the bed raised at a 45º angle. The patient was then instructed to squeeze the dynamometer as hard as possible to measure GS[16-18]. Three tests were performed on both the dominant and non-dominant hands at one-minute intervals in order to avoid muscle fatigue. The result was taken to be the highest score of the three attempts[18,19]. The test was performed in accordance with the recommendations of the American Society of Hand Therapists (ASHT)[18].

Indirect muscle strength was measured using the Medical Research Council Sum-Score (MRC-SS)[20]. Participants were considered eligible to participate in the study if they responded at least three of the five commands proposed by De Jonghe[21]: “open/close your eyes”; “look at me”; “open your mouth and put out your tongue”; “nod your head”; and “raise your eyebrows when I have counted up to five”. The following six muscle groups were graded on a scale of 0 to 5: abduction of the arm, flexion of the forearm, extension of the wrist, flexion of the hip, extension of the knee, and dorsal flexion of the foot[22]. A maximum score of 60 indicates normal muscle strength, 59 to 48 slight weakness, 47 to 36 significant weakness, and under 36 severe weakness[22]. The MRC-SS is a simple tool for assessing global muscle strength in intensive care patients and has good inter-rater reliability[22]. The tool has been translated into Portuguese and adapted for use in Brazil[20].

Respiratory muscle strength was tested according to maximal inspiratory pressure (MIP) using a respiratory pressure meter (MicroRPM®, Micro Medical, United Kingdom). The test was done with the participants seated on a chair with a backrest and armrest and undergoing continuous monitoring. Each participant was encouraged to make maximum voluntary expiratory effort at residual volume (RV) and then instructed to make maximum inspiratory effort to measure MIP. In accordance with American

Thoracic Society guidelines, three maneuvers with effort maintained for at least 1 second that varied by less than 20% were performed[23]. The values were recorded and compared with published normal values for the Brazilian population, using Neder et al.'s normalcy prediction equation as a frame of reference[24].

Dynamic inspiratory muscle strength was measured based on the S-Index and peak inspiratory flow (PIF), obtained using the POWERbreathe K5 (POWERbreathe International Ltd., Warwickshire, United Kingdom) with disposable filter nozzle and employing the same technique used to measure MIP described above. Ten maneuvers were performed with a 30-second rest between inspiratory maneuvers. The maximum value of the maneuvers was recorded[25-27].

STATISTICAL ANALYSIS

The categorical data were presented as absolute (n) and relative (%) frequencies and the continuous variables were described using medians and the interquartile range (IQR). The Kolmogorov-Smirnov test was used to check whether the data followed a normal distribution. All statistical tests were bilateral and adopted a 5% significance level ($\alpha = 0.05$). The data were divided into two periods: ICU admission (24 hours after surgery) and ICU discharge.

The Shapiro-Wilk test was used to show evidence of the non-normality of the clinical variables, followed by the Wilcoxon test for paired samples to provide evidence of eventual differences. Correlations between the test scores at admission and discharge were determined using Spearman's correlation coefficient. We assessed CPAx, IMS and MRC-SS performance at ICU admission and discharge using the floor and ceiling effects, calculated based on the percentage of patients scoring the lowest and highest values, respectively, for each tool. The statistical analyses were performed using R version 4.02.

SAMPLE SIZE

The appropriate sample size the CPAx (tested using the Wilcoxon test for paired samples) was calculated based on the means and respective standard deviations reported by Whelan in a pilot study with 85 patients conducted in 2018[28]: 32 and 44.35, respectively, and 11.34 and 9.66, respectively, considering a correlation of 0.48. Based on these measures it was possible to determine effect size using the Cohen method, resulting in 1.1711. Minimal sample size for a bilateral test was calculated using G Power version 3.1.9.7 based on a type I error of 0.05, type II error of 0.8, and effect of 1.1711, resulting in nine patients.

Results

Ninety-one of the 491 patients admitted to the ICU during the data collection period were eligible. Six of these patients were excluded (two patient deaths, one patient who refused to perform the second assessment, and three patients without laboratory tests), resulting in a final sample of 85 patients (Fig. 1)

The sample was predominantly female (62%) and the patients' median age was 59 years (IQR 53–71 years). The prognostic scores used to classify disease severity and organ dysfunction at ICU admission were low: APACHE II [8.7 (5.8–12.9)], SOFA [5 (4–6)], and SAPS II [23(14–29)]. The most common type of surgical procedure was gastrointestinal surgery (43.6%), which is classified as having a Class II surgical risk (51.8%).

Median surgery duration and duration of OTI was less than seven hours and general or regional anesthesia was used in 93% of patients. Mechanical ventilation (MV) was not required in the majority of patients (92.9%) (Table 1).

Table 1
Clinical characteristics of patients admitted to the ICU

Variables	General
	(n = 85)
Age, median (IQR)	59 (53–71)
Sex, female f (%)	53 (62.4)
BMI, median (IQR)	25.8 (23-29.4)
APACHE II, median (IQR)	8.7 (5.8–12.9)
SOFA, median (IQR)	5 (4–6)
SAPS II, median (IQR)	23 (14–29)
Type of cancer f (%)	
Central nervous system	25 (29.4)
Gastrointestinal	37 (43.6)
Lung	8 (9.4)
Prostrate	8 (9.4)
Leukemia	7(8.2)
Surgical risk f (%)	
I	25 (29.4)
II	44 (51.8)
III	15 (17.6)
IV	1(1.2)
Surgery duration (hrs), median (IQR)	5.8 (4.5–6.8)
duration of OTI (hrs), median (IQR)	5.2 (3.9–6.4)
Type of anesthesia f (%)	
General	39 (45.9)
Regional	40 (47.1)
Local	6 (7)

Data presented in medians and the interquartile range (IQR), absolute frequencies (f) and percent (%). BMI: Body Mass Index; APACHE II: Acute Physiology and Chronic Health Disease Classification System II; SOFA: Sequential Organ Failure Assessment; SAPS II: Simplified Acute Physiology; MV: mechanical ventilation; ICU: intensive care unit.

Variables	General
	(n = 85)
Use of MV at ICU admission f (%)	
No	79 (92.9)
Yes	6 (7.1)
Length of ICU stay (days), median (IQR)	2 (2–4)
Data presented in medians and the interquartile range (IQR), absolute frequencies (f) and percent (%). BMI: Body Mass Index; APACHE II: Acute Physiology and Chronic Health Disease Classification System II; SOFA: Sequential Organ Failure Assessment; SAPS II: Simplified Acute Physiology; MV: mechanical ventilation; ICU: intensive care unit.	

Source: authors' elaboration.

Table 2
Assessment of physical functioning, muscle strength and pulmonary function at ICU admission and discharge.

Variables	General		
	(n = 85)		
	Admission	Discharge	P
IMS, median (IQR)	6 (3–8)	9 (8–10)	*0.000*
CPAx score, median (IQR)	32 (23–41)	45 (41–49)	*0.000*
RGS (Kj/F), median (IQR)	24.5 (18–30)	26 (18–32)	*0.015*
LGS (Kj/F), median (IQR)	21.5 (16-29.8)	23 (18–30)	*0.000*
MRC-SS, median (IQR)	48 (42–48)	58 (48–60)	
MIP, median (IQR)	34 (23–47)	39.5 (28-56.3)	*0.000*
S-Index, median (IQR)	25.4 (20.7–33.4)	29.5 (22.1–37.3)	*0.000*
PIF (L/s), median (IQR)	1.3 (1-1.8)	1.6 (1.1–2.1)	*0.000*
Data presented in medians and the interquartile range (IQR), Wilcoxon test, significance level $p \leq 0.05$. IMS: ICU Mobility Scale; CPAx: Chelsea Critical Care Physical Assessment tool; RGS: right hand grip strength, LGS: left hand grip strength; Kj/F: kilojoules force; MRC-SS: Medical Research Council Sum-Score; MIP: maximal inspiratory pressure; S-Index: dynamic inspiratory muscle strength; PIF: Peak inspiratory flow; L/s: Liters per second.			
Source: authors' elaboration.			

Significant differences in functional status scores were observed between ICU admission and discharge: IMS [6 (3-8) *vs* 9 (8-10); p = 0.000] and CPAx [32 (23-41) vs 45 (41-49); p = 0.000] (Table 2, Figures 2.A, 2.B and 3). The findings also show differences in peripheral muscle strength between the two periods: RGS [24.5 (18-30) *vs* 26 (18-32); p = 0.015]; LGS [21.5 (16-29) *vs* 23 (18-30)]; and MRC-SS [48 (42-48 *vs* 58(48-60); p = 0.000] (Table 2 and Figures 2C, D and E). In the respiratory assessments, we observed significant differences for the variables MIP [34 (23-47) vs (39.5 (28-56.3); p=0.000], S-Index [25.4 (20.7-33.4) vs 29.5 (22.1-37.3); p=0.000] and PIF [1.3 (1-1.8) vs 1.6 (1.1-2.1);p=0.000] (Table 02 and Figures 2F, 2G and 2H).

MIP, S-Index and peak inspiratory flow scores also showed a significant change between ICU admission and discharge (p = 0.000; p = 0.000 and p = 0.000, respectively). Length of ICU stay had a positive influence, leading to a significant increase in scores (Figs. 2F, G and H).

The association analysis showed a weak correlation between IMS and CPAx scores at admission (r = 0.418; p = 0.00) and moderate correlation at discharge (r = 0.51; p = 0.00). There was a moderate correlation between RGS and LGS scores and MIP scores at both admission and discharge (r = 0.55; p = 0.00 and r = 0.52; p = 0.00 and r = 0.52; p = 0.00 and r = 0.51; p = 0.00, respectively). The findings also show a moderate correlation between S-Index scores and both MIP and peak inspiratory flow scores at admission (r = 0.58; p = 0.00 and r = 0.59; p = 0.00, respectively) and a strong correlation at discharge (r = 0.75; p = 0.00 and r = 0.74; p = 0.00, respectively).

Table 3
IMS, CPAx and MRC-SS performance at ICU admission and discharge.

Moment	Variables	Floor effect	Ceiling effect	Range
	IMS	9/85 (10.6%)	8/85 (9.4%)	1–10 of 10
Admission	CPAx	3/85 (3.5%)	3/85 (3.5%)	13–50 of 50
	MRC-SS	1/85 (1.2%)	14/85 (16.5%)	1–60 of 60
	IMS	2/85 (2.4%)	40/85 (47.1%)	1–10 of 10
Discharge	CPAx	1/85 (1.2%)	16/85 (18.8%)	23–50 of 50
	MRC-SS	3/85 (3.5%)	41/85 (48.2%)	36–60 of 60

Data presented as absolute frequencies (f) and percent (%). CPAx: Chelsea Critical Care Physical Assessment; IMS – ICU: Mobility Scale; MRC-SS: Medical Research Council Sum-Score.

Source: authors' elaboration.

The CPAx, IMS and MRC-SS showed floor and ceiling effects of 3.5 %, 10.6 % and 1.2%, and 3.5%, 9.4% and 16.5%, respectively, at ICU admission, and 1.2%, 2.4%, 3.5%, and 18.8%, 47.1% and 48.2%, respectively, at ICU discharge.

Discussion

This study identified a gradual increase in mobility, physical functioning, peripheral and respiratory muscle strength, and inspiratory flow during ICU stay.

The incidence of neoplasms in Brazil has risen sharply in recent years. This rise is partially attributable to population aging, which directly influences the incidence of cancer as somatic mutations arising from exposure to endogenous and exogenous agents are determining factors in the process of carcinogenesis. In addition, lifestyle factors such sedentarism, drinking and smoking increase the risk of developing cancer, especially among the younger population[29,30].

Cancer surgery is an important factor in the prognosis of cancer patients. However, prior assessment of surgical risk is an effective way of analyzing patient health status in order to estimate the probability of death and potential complications and define intervention and recovery strategies[31]. Our findings show that patients had a generally low surgical risk, which is consistent with the findings of previous studies reporting a reduction in prognostic indicators of disease severity and organ dysfunction at admission and risk of mortality[10,31–33]. In this regard, prior health status is a key factor influencing disease prognosis in cancer patients[31–33].

The most common types of cancer in Brazil after non-melanoma skin cancer are prostate cancer among men and breast cancer in women, followed by colon and rectum cancer[34]. Our findings show that the most common types cancers were those of the gastrointestinal tract, as the public hospital where the study was undertaken is a leading cancer treatment center.

Different tools are currently used to measure ICU mobility and physical functioning and which tool is used depends on the patient's situation[35]. Our findings show a decline in mobility in comparison to performance prior to admission. This decline is influenced by the type of surgery, surgical incision, sedation, mechanical ventilation and level of residual pain, which can restrict bed mobility and lead to immobility[36,37].

In the present study functional status was measured using the CPAx, with scores showing a gradual increase during ICU stay. In a study with intensive care burn patients, Corner et al. (2014)[16] observed that a six-point or more change in the CPAx score could be considered a clinically significant change in the physical function of ICU patients. Functional status is currently an important prognostic marker in intensive care cancer patients, meaning that assessment, monitoring and individualized interventions are essential to ensure comprehensive treatment or define appropriate palliative measures[38,39].

The patients in our study showed a gradual loss of peripheral muscle strength during ICU stay. Cancer accelerates loss of muscle strength, giving rise to muscle fatigue, cachexia and sarcopenia, and leading to functional decline[38]. In a study assessing patients with solid cancer, Norman et al.[40] reported that malnutrition, age and gender were factors contributing to reduced peripheral muscle strength, and muscle strength measured using a manual dynamometer was associated with functional status and quality of life.

Our findings also show a reduction in respiratory muscle strength. Loss of skeletal muscle mass is present in between 20 and 70% of cancer patients[41] and can affect respiratory muscles. Oxidative stress caused by cancer or chemotherapy can also cause muscle weakness, affecting respiratory muscles and increasing fatigue[41]. In addition, surgery and surgical incisions can also lead to a reduction in the contractile force of the diaphragm [31].

Our findings show a correlation between peripheral and respiratory muscle strength during ICU stay. O'Donnell et al.[42] also observed a correlation between peripheral and respiratory muscle strength, showing that breast cancer patients have general skeletal muscle weakness. Our findings also showed an association between MIP and dynamic muscle strength. Da Silva, et al.[26] presented similar results in a study assessing patients with chronic diseases, suggesting the use of the S-Index as a way of assessing inspiratory muscle strength.

The presence of floor and ceiling effects is an important consideration in the assessment of the effectiveness of therapeutic procedures adopted during admission to the ICU. A high floor effect suggests that test items are very difficult, while a high ceiling effect indicates that they are very easy, limiting the capacity to detect changes in physical function. Recent studies using quantitative measurement scales and tools reported functional decline in surgical patients during ICU stays[43], highlighting that the impairment of musculoskeletal and cardiovascular systems is a significant risk factor. The early identification of potential causes of system imbalance can therefore help define timely actions to interrupt these processes and improve treatment outcomes[43,44]. The floor and ceiling effects found in the present study show that the CPAx was the best-performing tool, suggesting that it is an effective tool for assessing surgical cancer patients.

This study has some limitations. First, the heterogeneity of the type and stage of the cancer meant that the patient sample was not homogeneous. Caution should therefore be taken when extrapolating these results to other populations. Second, the assessment of mobility prior to admission was self-reported, meaning that it may have been overestimated by the patient. Third, comprehensive assessments of body composition can result in a reduction in skeletal muscle strength. Four, it was not possible to monitor the patients after hospital discharge to investigate possible factors influencing muscle strength and physical functioning among the sample.

Conclusion

Our findings show a gradual improvement in mobility, physical functioning, peripheral and respiratory muscle strength, and inspiratory flow among surgical cancer patients admitted to the ICU.

Further research into mobility, physical functioning, and peripheral and respiratory muscle strength is needed to identify the mechanisms that influence changes in physical function and muscle strength after admission of surgical cancer patients to the ICU.

Declarations

Conflicts: the authors declare that there is no conflict of interest.

References

1. -Staudinger T, Stoiser B, Müllner M, Locker GJ, Laczika K, Knapp S, Burgmann H, Wilfing A, Kofler J, Thalhammer F, Frass M. Outcome and prognostic factors in critically ill cancer patients admitted to the intensive care unit. Crit Care Med. 2000 May;28(5):1322-8. doi: 10.1097/00003246-200005000-00011. PMID: 10834673.
2. -Mokart D, Etienne A, Esterni B, Brun JP, Chow-Chine L, Sannini A, Faucher M, Blache JL. Critically ill cancer patients in the intensive care unit: short-term outcome and 1-year mortality. Acta Anaesthesiol Scand. 2012 Feb;56(2):178–89. doi: 10.1111/j.1399-6576.2011.02579.x. Epub 2011 Dec 12. PMID: 22150473.
3. -Azoulay E, Afessa B. The intensive care support of patients with malignancy: do everything that can be done. Intensive Care Med. 2006 Jan;32(1):3–5. doi: 10.1007/s00134-005-2835-6. Epub 2005 Nov 25. PMID: 16308682.
4. -Martos-Benítez FD, Soto-García A, Gutiérrez-Noyola A. Clinical characteristics and outcomes of cancer patients requiring intensive care unit admission: a prospective study. J Cancer Res Clin Oncol. 2018 Apr;144(4):717–723. doi: 10.1007/s00432-018-2581-0. Epub 2018 Jan 23. PMID: 29362918.
5. -Hammond ME, Hayes DF, Dowsett M, Allred DC, Hagerty KL, Badve S, Fitzgibbons PL, Francis G, Goldstein NS, Hayes M, Hicks DG, Lester S, Love R, Mangu PB, McShane L, Miller K, Osborne CK, Paik S, Perlmutter J, Rhodes A, Sasano H, Schwartz JN, Sweep FC, Taube S, Torlakovic EE, Valenstein P, Viale G, Visscher D, Wheeler T, Williams RB, Wittliff JL, Wolff AC; American Society of Clinical Oncology; College of American Pathologists. American Society of Clinical Oncology/College of American Pathologists guideline recommendations for immunohistochemical testing of estrogen and progesterone receptors in breast cancer (unabridged version). Arch Pathol Lab Med. 2010 Jul;134(7):e48-72. doi: 10.5858/134.7.e48. PMID: 20586616.
6. -Moran MS, Schnitt SJ, Giuliano AE, Harris JR, Khan SA, Horton J, Klimberg S, Chavez-MacGregor M, Freedman G, Houssami N, Johnson PL, Morrow M. Society of Surgical Oncology-American Society for Radiation Oncology consensus guideline on margins for breast-conserving surgery with whole-breast irradiation in stages I and II invasive breast cancer. Int J Radiat Oncol Biol Phys. 2014 Mar 1;88(3):553 – 64. doi: 10.1016/j.ijrobp.2013.11.012. PMID: 24521674; PMCID: PMC4790083.
7. -Sledge GW, Mamounas EP, Hortobagyi GN, Burstein HJ, Goodwin PJ, Wolff AC. Past, present, and future challenges in breast cancer treatment. J Clin Oncol. 2014 Jul 1;32(19):1979-86. doi: 10.1200/JCO.2014.55.4139. Epub 2014 Jun 2. PMID: 24888802; PMCID: PMC4879690.
8. -Soares M, Caruso P, Silva E, Teles JM, Lobo SM, Friedman G, Dal Pizzol F, Mello PV, Bozza FA, Silva UV, Torelly AP, Knibel MF, Rezende E, Netto JJ, Piras C, Castro A, Ferreira BS, Réa-Neto A, Olmedo PB, Salluh JI; Brazilian Research in Intensive Care Network (BRICNet). Characteristics and outcomes of

patients with cancer requiring admission to intensive care units: a prospective multicenter study. Crit Care Med. 2010 Jan;38(1):9–15. doi: 10.1097/CCM.0b013e3181c0349e. PMID: 19829101.

9. -Rosolem MM, Rabello LS, Lisboa T, Caruso P, Costa RT, Leal JV, Salluh JI, Soares M. Critically ill patients with cancer and sepsis: clinical course and prognostic factors. J Crit Care. 2012 Jun;27(3):301–7. doi: 10.1016/j.jcrc.2011.06.014. Epub 2011 Aug 19. PMID: 21855281.
10. -Puxty K, McLoone P, Quasim T, Kinsella J, Morrison D. Survival in solid cancer patients following intensive care unit admission. Intensive Care Med. 2014 Oct;40(10):1409–28. doi: 10.1007/s00134-014-3471-9. Epub 2014 Sep 16. PMID: 25223853.
11. -von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP; STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. J Clin Epidemiol. 2008 Apr;61(4):344-9. doi: 10.1016/j.jclinepi.2007.11.008. PMID: 18313558.
12. -Hodgson C, Needham D, Haines K, Bailey M, Ward A, Harrold M, Young P, Zanni J, Buhr H, Higgins A, Presneill J, Berney S. Feasibility and inter-rater reliability of the ICU Mobility Scale. Heart Lung. 2014 Jan-Feb;43(1):19–24. doi: 10.1016/j.hrtlng.2013.11.003. Epub 2013 Nov 19. Erratum in: Heart Lung. 2014 Jul-Aug;43(4):388. PMID: 24373338.
13. -Kawaguchi, Yurika Maria Fogaça, et al. "Perme IntensiveCare Unit Mobility Score e UTI Mobility Scale: tradução e adaptação cultural para a língua portuguesa falada no Brasil." Jornal brasileiro de pneumologia 42 (2016): 429–434.
14. -Faria LM. Adaptação transcultural e validação do instrumento Chelsea Critical Care Physical Assessment (CPAx) para língua portuguesa. Tese (doutorado) - Universidade Federal de Santa Catarina, Centro de Ciências da Saúde, Programa de Pós-Graduação em Enfermagem, Florianópolis, 2018.
15. -Corner EJ, Wood H, Englebretsen C, Thomas A, Grant RL, Nikoletou D, Soni N. The Chelsea critical care physical assessment tool (CPAx): validation of an innovative new tool to measure physical morbidity in the general adult critical care population; an observational proof-of-concept pilot study. Physiotherapy. 2013 Mar;99(1):33–41. doi: 10.1016/j.physio.2012.01.003. Epub 2012 Mar 30. PMID: 23219649.
16. -Corner EJ, Soni N, Handy JM, Brett SJ. Construct validity of the Chelsea critical care physical assessment tool: an observational study of recovery from critical illness. Crit Care. 2014 Mar 27;18(2):R55. doi: 10.1186/cc13801. PMID: 24669784; PMCID: PMC4056321.
17. -Vaz M, Thangam S, Prabhu A, Shetty PS. Maximal voluntary contraction as a functional indicator of adult chronic undernutrition. Br J Nutr. 1996;76:9–15.
18. -Günther CM, Bürger A, Rickert M, Crispin A, Schulz CU. Grip strength in healthy Caucasian adults: reference values. J Hand Surg Am. 2008;33:558–65.
19. -Lopes J, Grams ST, da Silva EF, de Medeiros LA, de Brito CMM, Yamaguti WP. Reference equations for handgrip strength: Normative values in young adult and middle-aged subjects. Clin Nutr. 2018 Jun;37(3):914–918. doi: 10.1016/j.clnu.2017.03.018. Epub 2017 Mar 24. PMID: 28389120.

20. -Reis NFD, Biscaro RRM, Figueiredo FCXS, Lunardelli ECB, Silva RMD. Early Rehabilitation Index: translation and cross-cultural adaptation to Brazilian Portuguese; and Early Rehabilitation Barthel Index: validation for use in the intensive care unit. Rev Bras Ter Intensiva. 2021 Sep 20;33(3):353–61. doi: 10.5935/0103-507X.20210051. Epub ahead of print. PMID: 34550277; PMCID: PMC8555403.
21. -De Jonghe B, Bastuji-Garin S, Durand MC, Malissin I, Rodrigues P, Cerf C, Outin H, Sharshar T; Groupe de Réflexion et d'Etude des Neuromyopathies en Réanimation. Respiratory weakness is associated with limb weakness and delayed weaning in critical illness. Crit Care Med. 2007 Sep;35(9):2007-15. doi: 10.1097/01.ccm.0000281450.01881.d8. PMID: 17855814.
22. -Hermans G, Clerckx B, Vanhullebusch T, Segers J, Vanpee G, Robbeets C, Casaer MP, Wouters P, Gosselink R, Van Den Berghe G. Interobserver agreement of Medical Research Council sum-score and handgrip strength in the intensive care unit. Muscle Nerve. 2012 Jan;45(1):18–25. doi: 10.1002/mus.22219. PMID: 22190301.
23. -American Thoracic Society/European Respiratory Society. Statement on respiratory muscle testing. Am J Respir Crit Care Med 2002; 166:518–524.
24. -Neder JA, Andreoni S, Lerario MC, Nery LE. Reference values for lung function tests. II. Maximal respiratory pressures and voluntary ventilation. Brazilian Journal of Medical and Biological Research 1999;32(6):719–727.
25. -Silva PE, Carvalho KL, Frazão M, Maldaner V, Daniel CR, Gomes-Neto M. Assessment of Maximum Dynamic Inspiratory Pressure. Respir Care. 2018;63(10):1231–8.
26. -da Silva FMF, Cipriano G, Lima ACGB, Andrade JML, Nakano EY, Chiappa GR, Cahalin LP, Cipriano GFB. Maximal Dynamic Inspiratory Pressure Evaluation in Heart Failure: A Comprehensive Reliability and Agreement Study. Phys Ther. 2020 Dec 7;100(12):2246–2253. doi: 10.1093/ptj/pzaa165. PMID: 32941640.
27. -Langer D, Jacome C, Charususin N, Scheers H, McConnell A, Decramer M, Gosselink R. Measurement validity of an electronic inspiratory loading device during a loaded breathing task in patients with COPD. Respir Med. 2013 Apr;107(4):633–5. doi: 10.1016/j.rmed.2013.01.020. Epub 2013 Feb 17. PMID: 23421970.
28. -Whelan M, van Aswegen H, Corner E. Impact of the Chelsea critical care physical assessment (CPAx) tool on clinical outcomes of surgical and trauma patients in an intensive care unit: An experimental study. S Afr J Physiother. 2018 Aug 23;74(1):450. doi: 10.4102/sajp.v74i1.450. PMID: 30214949; PMCID: PMC6131696.
29. -White MC, Holman DM, Boehm JE, Peipins LA, Grossman M, Henley SJ. Age and cancer risk: a potentially modifiable relationship. Am J Prev Med. 2014 Mar;46(3 Suppl 1):S7-15. doi: 10.1016/j.amepre.2013.10.029. PMID: 24512933; PMCID: PMC4544764.
30. -DePinho RA. The age of cancer. Nature. 2000 Nov 9;408(6809):248 – 54. doi: 10.1038/35041694. PMID: 11089982.
31. -Bos MM, de Keizer NF, Meynaar IA, Bakhshi-Raiez F, de Jonge E. Outcomes of cancer patients after unplanned admission to general intensive care units. Acta Oncol. 2012 Sep;51(7):897–905. doi:

10.3109/0284186X.2012.679311. Epub 2012 May 1. PMID: 22548367.

32. -Caruso P, Ferreira AC, Laurienzo CE, Titton LN, Terabe DS, Carnieli DS, Deheinzelin D. Short- and long-term survival of patients with metastatic solid cancer admitted to the intensive care unit: prognostic factors. Eur J Cancer Care (Engl). 2010 Mar;19(2):260–6. doi: 10.1111/j.1365-2354.2008.01031.x. Epub 2009 Aug 26. PMID: 19709168.
33. -Cense HA, Hulscher JB, de Boer AG, Dongelmans DA, Tilanus HW, Obertop H, Sprangers MA, van Lanschot JJ. Effects of prolonged intensive care unit stay on quality of life and long-term survival after transthoracic esophageal resection. Crit Care Med. 2006 Feb;34(2):354 – 62. doi: 10.1097/01.ccm.0000195016.55516.3e. PMID: 16424714.
34. -Bray F, Ferlay J, Soerjomataram I, Siegel RL, Torre LA, Jemal A. Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin. 2018 Nov;68(6):394–424. doi: 10.3322/caac.21492. Epub 2018 Sep 12. Erratum in: CA Cancer J Clin. 2020 Jul;70(4):313. PMID: 30207593.
35. -Morris PE, Goad A, Thompson C, Taylor K, Harry B, Passmore L, Ross A, Anderson L, Baker S, Sanchez M, Penley L, Howard A, Dixon L, Leach S, Small R, Hite RD, Haponik E. Early intensive care unit mobility therapy in the treatment of acute respiratory failure. Crit Care Med. 2008 Aug;36(8):2238-43. doi: 10.1097/CCM.0b013e318180b90e. PMID: 18596631.
36. -Montagnani G, Vagheggini G, Panait Vlad E, Berrighi D, Pantani L, Ambrosino N. Use of the Functional Independence Measure in people for whom weaning from mechanical ventilation is difficult. Phys Ther. 2011;91(7):1109–15.
37. -Parry SM, Denehy L, Beach LJ, Berney S, Williamson HC, Granger CL. Functional outcomes in ICU - what should we be using?? - an observational study. Crit Care. 2015;19:127. http://dx.doi.org/10.1186/s13054-015-0829-5.
38. -Schnipper LE, Smith TJ, Raghavan D, Blayney DW, Ganz PA, Mulvey TM, Wollins DS. American Society of Clinical Oncology identifies five key opportunities to improve care and reduce costs: the top five list for oncology. J Clin Oncol. 2012 May 10;30(14):1715-24. doi: 10.1200/JCO.2012.42.8375. Epub 2012 Apr 3. PMID: 22493340.
39. -Lecuyer L, Chevret S, Thiery G, Darmon M, Schlemmer B, Azoulay E. The ICU trial: a new admission policy for cancer patients requiring mechanical ventilation. Crit Care Med. 2007 Mar;35(3):808 – 14. doi: 10.1097/01.CCM.0000256846.27192.7A. PMID: 17235261.
40. -Norman K, Stobäus N, Smoliner C, Zocher D, Scheufele R, Valentini L, Lochs H, Pirlich M. Determinants of hand grip strength, knee extension strength and functional status in cancer patients. Clin Nutr. 2010 Oct;29(5):586–91. doi: 10.1016/j.clnu.2010.02.007. Epub 2010 Mar 17. PMID: 20299136.
41. -Ryan AM, Power DG, Daly L, Cushen SJ, Ní Bhuachalla Ē, Prado CM. Cancer-associated malnutrition, cachexia and sarcopenia: the skeleton in the hospital closet 40 years later. Proc Nutr Soc. 2016 May;75(2):199–211. doi: 10.1017/S002966511500419X. Epub 2016 Jan 20. PMID: 26786393.

42. -O’Donnell et al. O'Donnell DE, Webb KA, Langer D, Elbehairy AF, Neder JA, Dudgeon DJ. Respiratory Factors Contributing to Exercise Intolerance in Breast Cancer Survivors: A Case-Control Study. J Pain Symptom Manage. 2016 Jul;52(1):54–63. doi: 10.1016/j.jpainsymman.2016.01.004. Epub 2016 Mar 11. PMID: 26975626.
43. -Parry SM, Granger CL, Berney S, Jones J, Beach L, El-Ansary D, Koopman R, Denehy L. Assessment of impairment and activity limitations in the critically ill: a systematic review of measurement instruments and their clinimetric properties. Intensive Care Med. 2015 May;41(5):744–62. doi: 10.1007/s00134-015-3672-x. Epub 2015 Feb 5. PMID: 25652888.
44. -Silva VZMD, Araújo JA Neto, Cipriano G Jr, Pinedo M, Needham DM, Zanni JM, Guimarães FS. Brazilian version of the Functional Status Score for the ICU: translation and cross-cultural adaptation. Rev Bras Ter Intensiva. 2017 Jan-Mar;29(1):34–38. doi: 10.5935/0103-507X.20170006. PMID: 28444070; PMCID: PMC5385983.

Figures

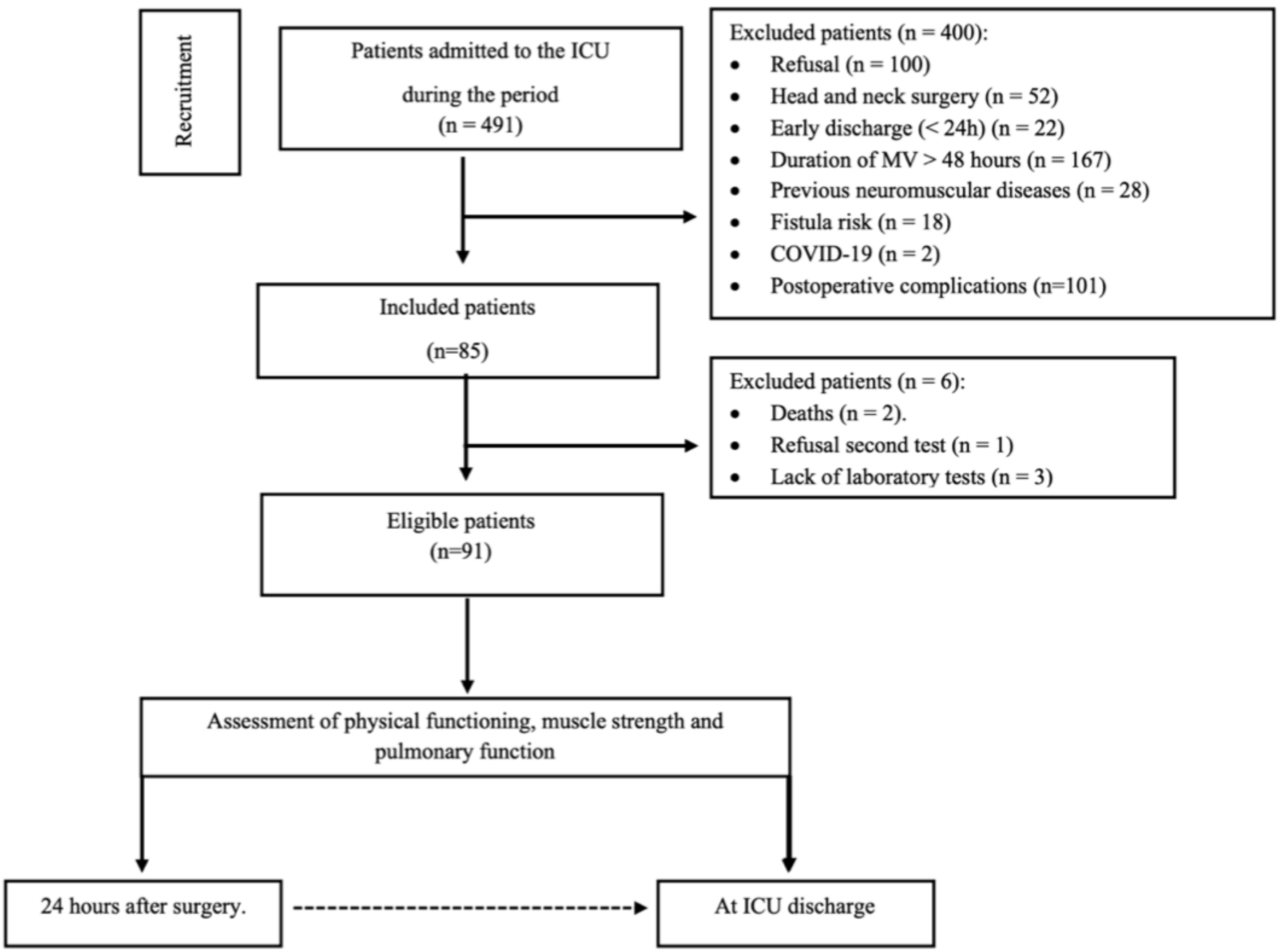


Figure 1

Flowchart of the cohort study process. Source: authors’ elaboration. Legend: ICU: Intensive Care Unit; MV: Mechanical ventilation.

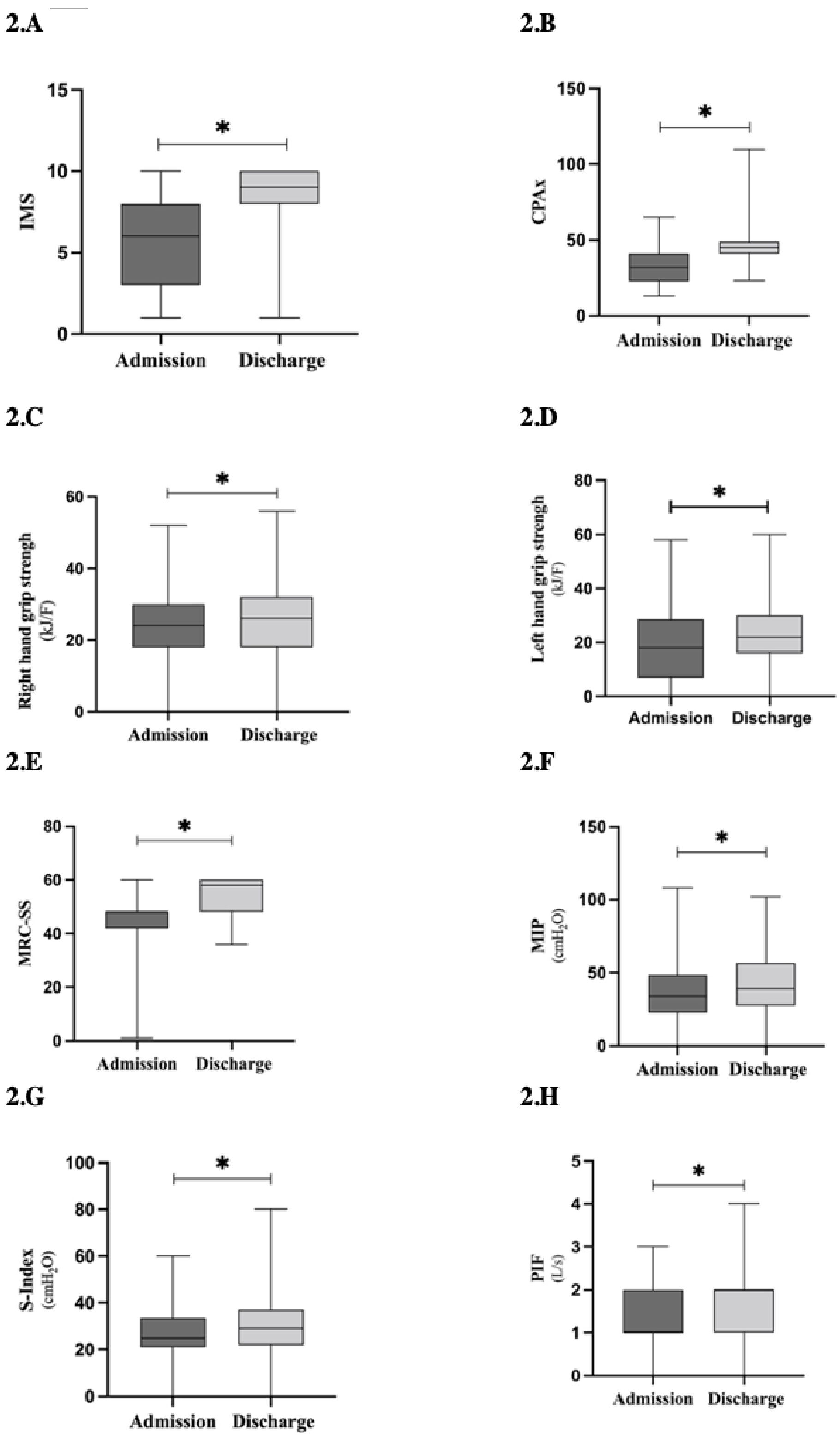


Figure 2

Comparison of IMS, CPAx, RGS, LGS MRC-SS, MIP, S. Index and PFI scores between ICU admission and discharge.

Legend: IMS: ICU Mobility Scale; CPAx: Chelsea Critical Care Physical Assessment tool; RGS: right hand grip strength, LGS: left hand grip strength; Kj/F: kilojoules force; MRC-SS: Medical Research Council Sum-Score; MIP: maximal inspiratory pressure; cmH_2O: centimeters of water; S-Index: dynamic inspiratory muscle strength; PIF: Peak inspiratory flow; L/s: Liters per second.

Source: authors' elaboration.

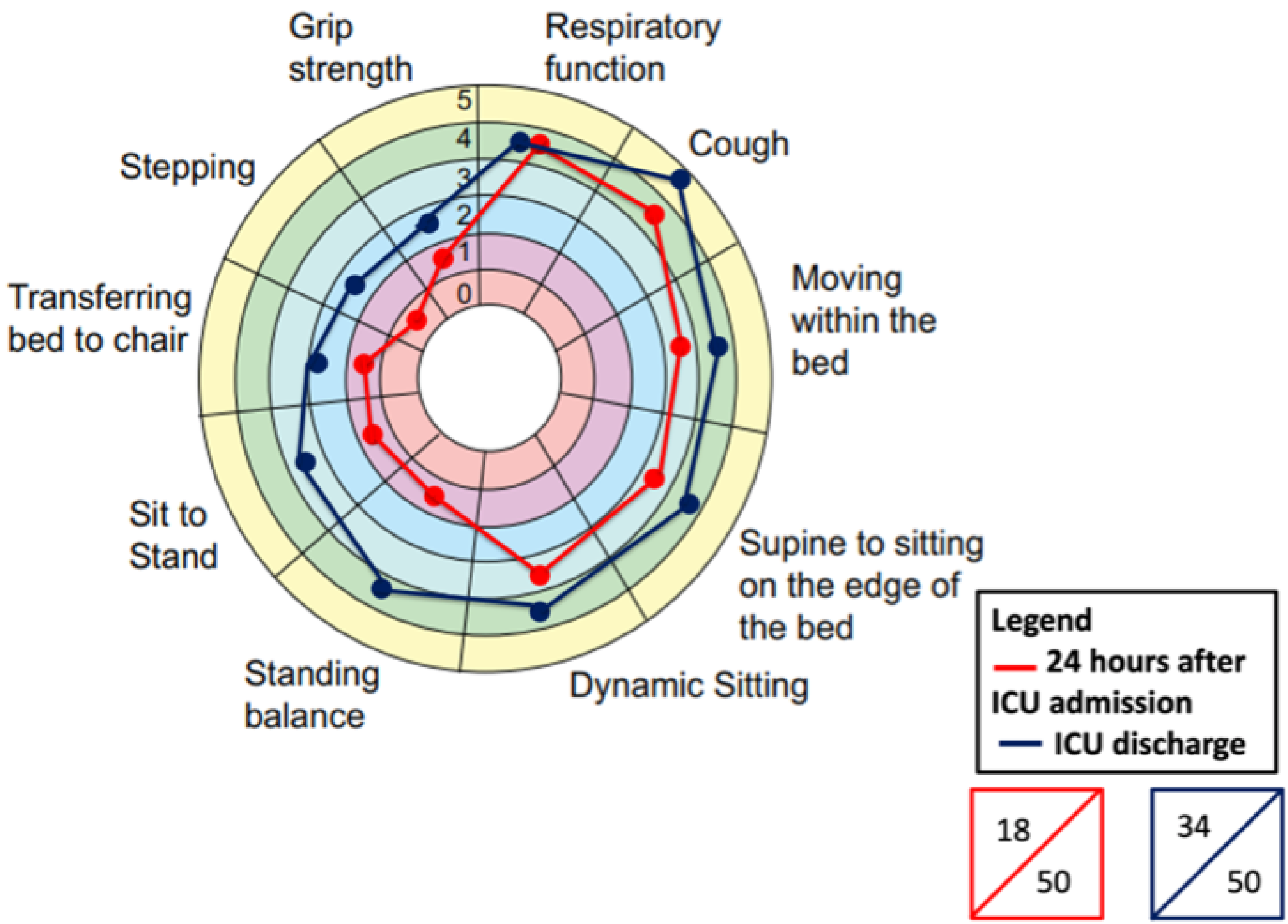
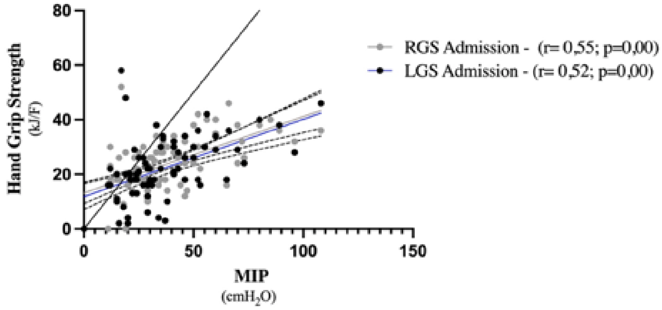


Figure 3

Median domain and overall Chelsea Critical Care Physical Assessment (CPAx) scores. Adapted from Faria et al.[14].

Legend: ICU: intensive care unit.

4.A



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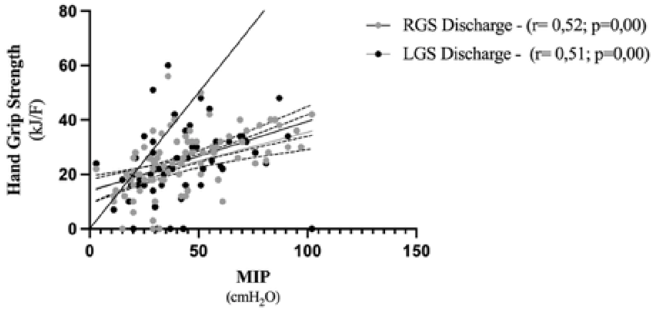

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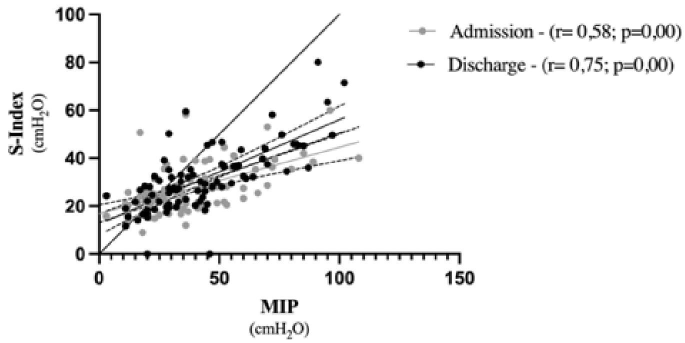

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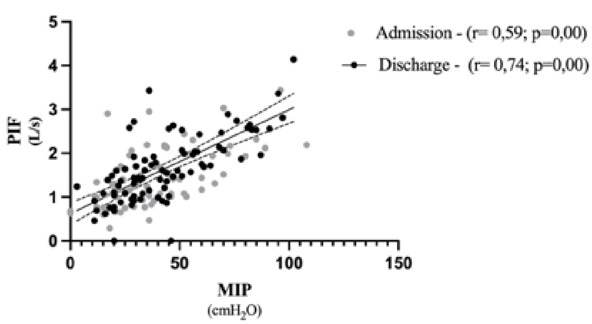

Figure 4

Correlation analysis of peripheral muscle strength and inspiratory muscle strength at ICU admission and discharge; r(adm) = correlation coefficient for admission data; r(discharge) = correlation coefficient for discharge data.

Legend: RGS: right hand grip strength, LGS: left hand grip strength; Kj/F: kilojoules force; MIP: maximal inspiratory pressure; S-Index: dynamic inspiratory muscle strength; cmH_2O: centimeters of water; PIF: Peak inspiratory flow; L/s: Liters per second.

Source: authors' elaboration.