

## Research Article

# The evaluation of nursing workload within an Italian ECMO Centre: A retrospective observational study <sup>☆</sup>



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## ABSTRACT

**Introduction:** The Nursing Activities Score (NAS) measures the amount of nursing time required for each patient and it has been widely used across Europe since its first validation in 2003.

**Objective:** To determine the nursing workload within an Extracorporeal Membrane Oxygenation (ECMO) Centre using a dedicated scoring tool.

**Methods:** Retrospective observational study. Data from NAS were collected for seventy-two consecutive months from January 2010.

**Results:** A total amount of 2606 patients were enrolled. Their median NAS recorded at Intensive Care Unit's admission was 69.8 (IQR: 56.2–82.9), whilst the daily average NAS was 68.1 (IQR: 58.3–76.7). ECMO patients enrolled were 95 (4%), with 3141 ECMO days. The median NAS of the ECMO patients versus patients without ECMO support was 87.0 (IQR: 82–96) and 67.2 (IQR: 58–78) respectively ( $p < 0.0001$ ). The number of daily ECMO treatments showed a slight correlation with the average daily NAS ( $r = 0.176$ – $p < 0.0001$ ).

**Conclusions:** Our findings suggest that in ECMO patients a nurse-to-patient ratio equal to 1:1, should be guaranteed in accordance to the national health regulations and organizations. The results of this study reinforce the current recommendation about the implementation of referral ECMO centres, in order to centralise patients, provide a dedicated clinical-technical support and also guarantee an adequate number of ECMO nurses supported by an accurate nurse management.

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## Implications for clinical practice

- Accurate recording of Nursing Activities Score in critically ill patients represents a crucial step in the evaluation of the most suitable nurse-to-patient ratio
- Nursing workload in an ICU performing as ECMO referral centre may be affected from the amount of patients treated simultaneously by ECMO support
- During ECMO the nurse-to-patient ratio should be 1:1

<sup>☆</sup> The present study was performed at the General Intensive Care Unit, Emergency Department and Intensive Care, San Gerardo Hospital – ASST Monza, Via Pergolesi 33 – Monza (MB), Milan-Bicocca University – Italy.

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## Introduction

In 2009, the Italian Health Authorities set up a national referral network of selected intensive care units (ICUs) able to provide techniques of advanced respiratory care and extracorporeal membrane oxygenation support (ECMO) for patients affected by acute respiratory distress syndrome (ARDS) (Patroniti et al., 2011). This network, known as 'ECMOnet', has treated more than 400 patients with ECMO since its establishment, through a "Hub and spoke" organisation. Currently, the implementation of dedicated ECMO centres characterised by a high-volume of treated patients (at least 30 patients per year), is highly recommended by the scientific literature (Barbaro et al., 2015) and it seems to improve the survival rate plus reducing the adverse events related to ECMO. The Italian Health Authorities have provided extra funding for selected centres to improve these technical equipment and medical devices, but at the same time no funding has been planned to strengthen medical and nurse staffing in order to cope with the increased volume of cases (Patroniti et al., 2011). The nurse staffing of an ECMO centre, in addition to the standard nursing care for critically ill patients, are expected to perform specific procedures like inspecting the extracorporeal circuit for its integrity, early detection of clots, bubbles (air accumulation) or leakage and to preserve the patient's safety during positioning therapy. ARDS patients treated with ECMO support, often require advanced bedside-procedures such as prone positioning, early mobilisation, placement of a pulmonary artery catheter (PAC) or a daily bronchoscopy (Wells et al., 2018; Lucchini et al., 2018a,b). Nevertheless, patients usually receive large amounts of sedatives drugs, paralysing agents, intravenous fluids, blood's products and often one or more vasopressors drugs. Because the severity of illness, also patients' relatives require adequate emotional support and empathy from nurses. In a recent position paper Combes et al. (2014) suggested a nurse-to-patient ratio of 1:2/1:1 during ECMO. However, a nurse-to-patient ratio higher than two nurses for one patient has been reported (Bibro et al., 2011). Centralising ECMO patients appears to be useful because this strategy leads to a 3:2 nurse-to-patient ratio, able to support high volume of ECMO patients at any given time. The previous mentioned ratio seldom will be match the Italian's ICUs, because the accreditation's standards for intensive care beds require a nurse-to-patient ratio equal to 1:2. Nursing workload and identifying the most suitable nurse-to-patient ratio are currently hot topics in the available scientific literature. Most of the studies selected about nursing workloads and staffing, were designed and performed using the Nursing Activities Score (NAS), developed by Miranda and colleagues in 2003 (Miranda et al., 2003) on a basic principle: nursing care is not only defined by the severity of illness and therapeutic procedures. NAS score is made up of 13 main areas (sections), split into 23 items, able to describe the patient (and non-patient) related tasks, administrative activities, and the level of patient's dependency. The resulting score, worked out by percentage, represents the total amount of time required to deliver nursing care. A score equal to 100%, represents one nurse dedicated to assist a patient over 24 hours (nurse-to-patient ratio 1:1, equal to 1440 min of nursing care). The average value of NAS for an ICU will determine the level of nursing workload. This scoring tool has been used in Brasil (Ducci et al., 2008; Padilha et al., 2008, 2010), in Italy (Lucchini et al., 2013, 2014, 2015), in Norway (Stafseth et al., 2011, 2018), in Spain (Carmona-Monge et al., 2013) and in Poland (Cudak and Dyk, 2010). Lucchini et al. (2014) also investigated the nursing workload (based on NAS) for ICU patients supported by ECMO. The highest NAS score recorded in that study, was related to the presence of the extracorporeal support (ECMO) with a median value of 102 (IQR: 85-122) for patients on veno-venous ECMO and 87 (IQR:

70-102) for those supported by veno-arterial ECMO (Lucchini et al., 2014).

Centralisation of ECMO patients requires high nurse-to-patient ratio, moreover, during the seasonal-flu pandemic time of the year (Paden et al., 2013; Combes et al., 2014), it could increase the levels of ICUs' workload in every aspect: direct related task (patient's needs) and non-direct related aspects (organisation/management), requiring the staff to accomplish the usual routine care plus the management of ECMO patients' specific needs. In addition, these ECMO referral centres should provide a mobile ECMO team available 24/7, to perform the ECMO support placement in any hospitalised patient in a wide district area and transfer these patients to their own centres to carry on with advance treatments (Patroniti et al., 2011; Combes et al., 2014). Currently there are no published studies investigating the influence of ECMO patients centralisation (and their increased number), on global nursing workload in a ECMO referral centre.

## Objective

The primary aim of this study was to retrospectively analyse the mean NAS level of patients at their admission's time and the mean daily NAS of a referral Italian ECMO Centre, highlighting any differences in nursing workload between ECMO patients and not ECMO patients. Secondary aims were to determinate the relationships between NAS and the following variables: sedation levels measured by the Richmond Agitation Sedation Scale (RASS) (Sessler et al., 2002), the severity of illness measured by the Simplified Acute Physiology Score III (SAPS 3) (Poole et al., 2009), the ICU length of stay (LOS), and the patients' age.

## Materials and methods

### Study design and setting

A retrospective case review was performed, enrolling all patients admitted in a referral ECMO centre of an Italian University Hospital, from 1st January 2010 until 31st December 2015. The authors' institution has served as a national centre for lung rescue via veno-venous ECMO since 1989. A mobile program for inter-facility transport of patients on ECMO stabilizing therapy was initiated in 2004.

The ICU is an eight-bedded unit (4 rooms with two beds), operating 24 hours a day/7 days a week plus two beds dedicated for post-surgical patients, available from Monday morning to Saturday afternoon. These two beds are dedicated to patients undergoing elective surgery with a planned overnight stay in ICU. Short periods of extended recovery care, typically up to one day, have been advocated to allow correction of abnormal physiology, short periods of postoperative ventilation, interventions such as goal-directed haemodynamic therapy, or components of an enhanced recovery after surgery (ERAS) intervention (Ljungqvist et al., 2017).

In the ICU, during the study period the nursing staff was composed of 30 nurses (among which ten were university certified critical care nurses), five nurses assistants and a perfusionist on call. The daily shifts were made up of seven nurses in the morning, six nurses in the afternoon and five in the nightshift. A nurses assistant is guaranteed over the 24 hours. Usually physical restraints are not employed in the ICU.

### Data collection

All the studied parameters were recorded using the software Drager Medical Innovian SUITE® patient management system. NAS was developed on a basic principle: nursing care is not defined

only by the severity of illness and therapeutic procedures. NAS score is made up of 13 main areas, split into 23 items, describing patient-related and non-patient-related works, administrative tasks and the level of the patient's dependency. The resulting score, worked out by percentage, represents the total amount of time required to deliver nursing care. A NAS score of 100% corresponds to one nurse dedicated to a single patient over 24 hours (nurse-to-patient ratio 1:1 equal to 1440 minutes of nursing care/day). The workload was assessed through an Italian version of NAS (Lucchini et al., 2008, 2011). The NAS of every patients was compiled at 6 a.m. by the nurse who had him/her in charge, reporting the previous 24 hours. Every ICU nurse uses NAS daily. Nurse have received special training to use NAS, since their initial period of working in ICU. The NAS filling criteria were the same to those recently published by Padilha et al. (2015). Table 1 summarises the NAS items and updated guideline for its application, according to Padilha et al. (2015).

With the aim to highlight possible differences in NAS scoring, after having enrolled patients, they were classified on the basis of their admitting departments (General Surgery, General Medicine, Emergency, Neurology, Cardiology, Haematology, Other ICUs) and if their admission was through Mobile ECMO team mission. The Simplified Acute Physiology Score III (SAPS 3) is an ICU scoring system and is used to predict the mortality risk for patients staying in ICU. The SAPS 3 was compiled at ICU's admission. The Richmond Agitation-Sedation Scale was completed four times a day for each patient. The RASS is a medical scale used to measure the agitation or sedation level of a person. The RASS can be used in all hospitalised patients to describe their level of alertness or agitation. RASS is a 10-point scale, with four levels of anxiety or agitation (+1 to +4 [combative]), one level to denote a calm and alert state (0), and 5 levels of sedation (-1 to -5) culminating in unarousable (-5). The association SAPS 3/NAS was investigated in order to find a possible correlation between clinical severity and therapeutic interventions. Analysis of the association between RASS and NAS aims to showing an existing correlation between the average level of sedation and NAS during the ICU stay.

#### Ethical considerations

The study protocol was evaluated by the local Ethics Committee, which waived a written informed consent due to the retrospective study design. The local Ethics Committee approved this study on 15/05/2018 (approval progressive number: 877). All the enrolled patients or their relatives were informed that data from their ICU's experience could be collected for clinical research purpose.

#### Data analysis

All data were analysed using the Statistical Social Sciences software, version 22.0, for Windows (SPSS Inc., Chicago, IL, USA). The average, standard deviation, median, interquartile ranges and range were calculated for all variables. Quantitative variables were compared using non-parametric test (Kruskal-Wallis H test). The Kruskal-Wallis H test is a rank-based nonparametric test that can be used to determine if there are statistically significant differences between two or more groups of an independent variable. Spearman's correlation analysis were utilised, and  $p = 0.01$  (2-tailed) was considered to be significant. The Spearman correlation express the strength of association between two variables in a single value between -1 and +1. A positive correlation coefficient indicates a positive relationship between the two variables (as values of one variable increase, values of the other variable also increase) while a negative correlation coefficient expresses a negative relationship (as values of one variable increase, values of the other variable

decrease). A correlation coefficient of zero indicates that no relationship exists between the variables.

#### Results

The total number of patients enrolled was 2606. The median age of the investigated population was 67.0 (IQR: 51.0–76.0 – range 1–97) years, while the length of ICU stay (LOS) was 2 (IQR: 1–5 – range 1–128) days. For each patient the median NAS for the entire ICU LOS was 68.1 (IQR: 58.3–76.7 – range: 28–140), at ICU admission's day was 69.8 (IQR: 56.2–82.9 – range: 49–147) and 62.4 (IQR: 52.6–73.7 – range: 28–147) the day before the ICU's discharge. The median NAS based on every patient's score during each day of the six investigated years was 75.3 (IQR: 59.2 – 91.1 range 45–110), with a bed occupancy rate  $85 \pm 13\%$  (range: 33–117%). The median SAPS 3 recorded was 34.0 (IQR: 23.0–48.5 – range: 5–108), whilst the median RASS concerning the whole ICU stay was -1 (IQR: -2/0). The median of nurse-to-patient ratio (care giving nurses) during the interval of time investigated was  $0.61 \pm 0.04$ . The correlation between mean patient NAS and SAPS 3 was  $r = 0.25$  in 2302 pairs ( $p < 0.0001$ ), NAS and LOS was  $r = 0.27$  in 2606 pairs ( $p < 0.0001$ ), NAS and age was  $r = -0.081$  in 2606 pairs ( $p = 0.0001$ ), NAS and RASS was  $r = -0.37$  in 2606 pairs ( $p = 0.0001$ ). On a basis of the hospital's set-up, the selected departments were: general surgery, general medicine, emergency, neurology, cardiology, haematology, intensive care (including transfers from others ICUs) and patient transported on ECMO by mobile ECMO team. Table 2 shows data about NAS divided according to the admissions department.

In the studies time span, 95 (4%) patients underwent ECMO support (ECMO/year: 2010  $n = 10$ , 2011  $n = 13$ , 2012  $n = 12$ , 2013  $n = 16$ , 2014  $n = 19$ , 2015  $n = 25$ ), resulting a total of ECMO days equal to 3141. Elective postoperative patients were 841 (32%), and other ICU patients were 1670 (64%). 90 patients were treated by veno-venous ECMO (94%) whilst 5 patients by veno-arterial ECMO (6%). In 449 days (20%) the number of patients on ECMO was zero, in 770 days (35%) there was at least one patient in ECMO, on 632 (29%) days 2 patients simultaneously, on 256 (12%) days 3 patients and on 79 days (4%) 4 patients. Only 5 days (0.2%) were distinguished by the presence of five ECMO patients at the same time. The median NAS during hospital stay of ECMO patients was 87.2 (IQR: 82.1–95.60) versus 69.4 (IQR: 62.0–76.4) of ordinary ICU's patients versus 63.1 (IQR: 53.0–74.5) of elective postoperative patients ( $p < 0.0001$ ). Table 3 summarise differences existing between ECMO patients and the rest of enrolled patients. The correlation between patients' median NAS on daily basis and number of daily ECMO procedures was  $r = 0.176$  ( $p < 0.0001$ ). The median NAS value were: 73.9 (IQR: 69.5–78.9) during the days off from ECMO treatments; 75.1 (IQR: 70.6–80.0) with presence of one ECMO patient; 75.4 (IQR: 71.1–81.2) with two ECMO patients; 77.7 (IQR: 73.0–82.7) with three ECMO patients; 78.6.1 (IQR: 74.1–82.2) with four ECMO patients; and 79.9 (IQR: 78.8–79.9) with 5 ECMO patients ( $p < 0.0001$ ). The correlation between number of daily ECMO patients and daily bed turnover rate was  $r = 0.135$  ( $p < 0.0001$ ). Fig. 1 shows the number of patients for each days treated by ECMO and the mean daily NAS during the study period.

#### Discussion

In the present study, the median NAS per patient is equal to 68.1 (IQR: 58.3–76.7), this was similar to the value recorded in other studies: 69.3% (Goncalves et al., 2007); 59.6% (Ducci et al., 2008); 66.0% (Lucchini et al., 2014), although much lower than reported in another Norwegian study (Stafseth et al., 2011) where

**Table 1**  
Nursing Activities Score – Guideline for its application, according to Padilha et al. (2015).

BASIC ACTIVITIES	SCORE
<b>1. MONITORING AND TITRATION</b>	
<b>1a. Hourly vital signs, regular registration and calculation of fluid balance</b>	<b>4.5</b>
Patients who require NORMAL monitoring, according to the ICU routine, of vital signs, application of assessment scales (pain, RASS, Glasgow), water balance control (including nasogastric tubes) and who do not need frequent alterations in treatment, therapy or monitoring intensification. Assisted oral feeding.	
<b>1b. Present at bedside and continuous observation or active for 2 h or more in any shift, for reasons of safety, severity or therapy, such as: non-invasive mechanical ventilation, weaning procedures, restlessness, mental disorientation, prone position, donation procedures, preparation and administration of fluids and/or medication, assisting specific procedures.</b>	<b>12.1</b>
Patients who require intensified monitoring (MORE THAN NORMAL) due to alterations in the clinical condition, hemodynamic instability, oliguria, bleeding, dyspnoea, fever, alteration in the level of consciousness, measurements in the assessment scales higher than the ICU standard, measurement of central venous pressure, invasive arterial pressure, intra-abdominal pressure, use of sedatives or long-term use of insulin, ventilator support, non-invasive mechanical ventilation or alteration of the ventilator parameters, preparation of fluids and emergency medication. Patient is stable after the therapeutic behaviour adopted. Immediate post-operative care after cardiac surgery or major surgery, where the patient remains stable. Invasive procedures with interurrences. Extubation without interurrences. Assisted oral feeding that demands more time than normal.	
<b>1c. Present at bedside and active for 4 h or more in any shift for reasons of safety, severity or therapy – examples above (1b).</b>	<b>19.6</b>
Critical patients who require MUCH MORE THAN NORMAL monitoring, in at least one shift in 24 h, without stabilization after the therapeutic interventions adopted, requires continuous nursing presence. Alterations described in the "MORE THAN NORMAL" category, however with a greater frequency and the need for interventions. Haemodialysis with interurrence, requiring nursing intervention (when haemodialysis is performed by ICU staff). Unstable patients in immediate postoperative care after cardiac surgery or major surgery.	
<b>2. LABORATORY: Biochemical and microbiological investigations.</b>	<b>4.3</b>
Patients submitted to any biochemical or microbiological exam, regardless of the quantity, performed at bedside by a nursing professional, including capillary glucose. E.g.: HGT, glycosuria, tracing cultures, blood gas analysis, among others. This item should not be scored if the laboratory collector or physician performs the collection.	
<b>3. MEDICATION: Vasoactive drugs excluded.</b>	<b>5.6</b>
Patients who received any type of medication, regardless of the route and dose. Vasoactive drugs will be scored in a specific item (item 12).	
<b>4. HYGIENE PROCEDURES</b>	
<b>Performing hygiene procedures such as: dressing of wounds and intravascular catheters, changing linen, washing patient, incontinence, vomiting, burns, leaking wounds, complex surgical dressing with irrigation, special procedures (e.g. barrier nursing, cross-infection related, room cleaning following infections, staff hygiene) and especially obese patients, etc.</b>	
<b>4a. NORMAL</b>	<b>4.1</b>
Patients who were submitted, in NORMAL frequency (ICU routine), to one of the hygiene procedures mentioned above in at least one shift in 24 h. Also including dressings closed in vascular catheter once a day.	
<b>4b. The performance of hygiene procedures took more than 2 h in any shift.</b>	<b>16.5</b>
Patients who were submitted, in MORE THAN NORMAL frequency, to one of the hygiene procedures mentioned above in at least one shift in 24 h. Vascular catheter dressing twice a day; medium dressing for pressure ulcer, dressing a surgical incision twice a day, medium dressing (with suture dehiscence); changing linen twice in 24 h; washing of unstable patients by three professionals; body hygiene twice per shift. Fecal incontinence three times a day. Patients in isolation.	
<b>4c. The performance of hygiene procedures took more than 4 h in any shift.</b>	<b>20.0</b>
Patients who were submitted, in MUCH MORE THAN NORMAL frequency, to one of the hygiene procedures mentioned above in at least one shift in 24 h. Extensive, complex, open cavity dressing or ≥ three times a day.	
<b>5. CARE OF DRAINS – All (except gastric tube).</b>	<b>1.8</b>
Patients with any type of drain or tube with the aim of draining. Including long-term catheter, external ventricular drain, thorax drain, among others. EXCLUDING gastric tubes (nasogastric, nasoenteral, gastrostomies and others), which should be considered in item 1 or 21.	
<b>6. MOBILIZATION AND POSITIONING</b>	
<b>Including procedures such as: turning the patient; mobilization of the patient; moving from bed to chair; team lifting (e.g. immobile patient, traction, prone position).</b>	
<b>6a. Performing procedure(s) up to 3 times per 24 h.</b>	<b>5.5</b>
Patients who require mobilization and positioning up to three times in 24 h.	
<b>6b. Performing procedure(s) more frequently than 3 times per 24 h, or with 2 nurses – any frequency.</b>	<b>12.4</b>
Patients who require mobilization and positioning, as described in item 6, which have been performed more than three times in 24 h or by two members of the nursing staff in at least one shift in 24 h.	
<b>6c. Performing procedure with three or more nurses – any frequency.</b>	<b>17.0</b>
Complex mobilization and positioning as per the procedure described in item 6, which have been performed by three or more members of the nursing staff, in any frequency, in at least one of the shifts in 24 h.	
<b>7. SUPPORT AND CARE OF RELATIVES AND PATIENT</b>	
<b>Including procedures such as telephone calls, interviews. Often, the support and care of either relatives or patient allow staff to continue with other nursing activities (e.g.: communication with patients during hygiene procedures, communication with relatives whilst present at bedside and observing patient).</b>	
<b>7a. Support and care of either relatives or patient requiring full dedication for about one hour in any shift such as: to explain clinical condition, dealing with pain and distress, difficult family circumstances.</b>	<b>4.0</b>
This item receives a score when guidance or instructions are given to patients and/or their families, providing emotional support with full dedication of a nurse from the staff, with NORMAL duration, according to the routine established in the unit, in at least one shift in 24 h.	
<b>7b. Support and care of either relatives or patient requiring full dedication for 3 h or more such as: to explain clinical condition, dealing with pain and distress, difficult family circumstances.</b>	<b>32.0</b>
This item receives a score when guidance or instructions are given to patients and/or their families, providing emotional support with full dedication of a nurse from the staff, with MORE THAN NORMAL duration, according to the routine established in the unit, in at least one shift in 24 h.	
<b>8. ADMINISTRATIVE AND MANAGERIAL TASKS</b>	
<b>8a. Performing routine tasks such as: processing of clinical data, ordering examinations, professional exchange of information (e.g.: ward rounds).</b>	<b>4.2</b>
Including records performed as nursing process and/or shift change, multidisciplinary rounds or administrative and managerial tasks related to patients, with NORMAL duration.	
<b>8b. Performing administrative and managerial tasks requiring full dedication for about 2 h in any shift such as: research activities, protocols in use, admission and discharge procedures.</b>	<b>23.2</b>
Including records performed as part of nursing process and/or shift change, multidisciplinary rounds or administrative and managerial tasks related to patients, with MORE THAN NORMAL duration. Admission of patients in immediate postoperative period, unstable patients who require more extensive records. Need for providing materials and equipment. Assembly of the haemodialysis machine, application of protocols such as ECMO, transplantation, others. When the nurse needs help from a colleague to perform his/her activities. E.g.: the nurse continues assisting a patient and a colleague takes over the administrative tasks.	

Table 1 (continued)

BASIC ACTIVITIES	SCORE
<b>8c. Performing administrative and managerial tasks requiring full dedication for about 4 h or more of the time in any shift such as: death and organ donation procedures, co-ordination with other disciplines.</b> Including any administrative and managerial task related to the patient, with <b>MUCH MORE THAN NORMAL</b> duration, according to the routine established in the unit. Critical, unstable patients who require intense records. Detailed shift change records, multidisciplinary rounds, organization of special materials and equipment for patient care, surgical procedures at bedside, protocols such as transplantation, ECMO, ventricular assist devices, teaching and supervising education/training.	<b>30.0</b>
<b>VENTILATORY SUPPORT</b>	
<b>9. Respiratory support: Any form of mechanical ventilation/assisted ventilation with or without positive end-expiratory pressure, with or without muscle relaxants; spontaneous breathing with positive end-expiratory pressure (e.g. CPAP or BiPAP), with or without endotracheal tube; supplementary oxygen by any method.</b> Patients making use of any respiratory support, from nasal catheter to mechanical ventilation.	<b>1.4</b>
<b>10. Care of artificial airways. Endotracheal tube or tracheostomy cannula.</b> Patients making use of orotracheal or nasotracheal tube or tracheostomy.	<b>1.8</b>
<b>11. Treatment for improving lung function. Lung physiotherapy, incentive spirometry, inhalation therapy, intratracheal suctioning.</b> Patients who underwent treatment to improve their pulmonary function, performed in any frequency by the nursing staff. Aspiration with open or closed system and nebulization.	<b>4.4</b>
<b>CARDIOVASCULAR SUPPORT</b>	
<b>12. Vasoactive medication, irrespective of type or dose.</b> Patients who have received any vasoactive medication, regardless of the type and dose and who need intensive monitoring in their endovenous use: Sodium Nitroprusside, Vasopressin, Prostaglandin, Norepinephrine, Epinephrine, Dopamine, Dobutamine, Isoproterenol, Phenylephrine, Nitroglycerin., Metoprolol and Propranolol (beta blockers) should be scored.	<b>1.2</b>
<b>13. Intravenous replacement of large fluid losses. Fluid administration greater than 3 l/m<sup>2</sup>/day, irrespective of type of fluid administered.</b> Patients who have received fluid replacement greater than 4.5 Lt. of solution per day, irrespective of the type of fluid administered.	<b>2.5</b>
<b>14. Left atrium monitoring. Pulmonary artery catheter with or without cardiac output measurement.</b> Patients making use of pulmonary artery catheter (Swan-Ganz catheter). Including the use of cardiac pacemaker, intra-aortic balloon pumping, cardiac output monitoring, extracorporeal life support (ECLS), ventricular assist devices.	<b>1.7</b>
<b>15. Cardiopulmonary resuscitation after arrest; in the past 24 h (single precordial thump not included).</b> Patients who suffered a heart problems and were submitted to cardiopulmonary resuscitation, independently of the environment where the cardiac arrest took place. This item should be scored only once in 24 h.	<b>7.1</b>
<b>RENAL SUPPORT</b>	
<b>16. Hemofiltration techniques. Dialysis techniques.</b> Patients who have received any type of intermittent or continuous dialytic procedure.	<b>7.7</b>
<b>17. Quantitative urine output measurement (e.g.: by indwelling urinary catheter).</b> Patients who require diuresis control, with or without any type of urinary device.	<b>7.0</b>
<b>NEUROLOGICAL SUPPORT</b>	
<b>18. Measurement of intracranial pressure.</b> Patients submitted to intracranial pressure monitoring, jugular bulb catheter or microdialysis. Do consider this item if the patient has external ventricular drainage and assessment of ICP.	<b>1.6</b>
<b>METABOLIC SUPPORT</b>	
<b>19. Treatment of complicated metabolic acidosis/alkalosis.</b> Patients who made use of specific medication to adjust metabolic acidosis or alkalosis, such as administration of sodium bicarbonate in continuous or bolus infusion. Respiratory acidosis and alkalosis should not be scored in this item, neither should ventilator correction. The item considers those conditions requiring the permanent presence of a nurse for monitoring severe physiological deregulation and for titrating (fine-tuning) the therapy in acute conditions. During hemofiltration, if correction is necessary, additional score is indicated.	<b>1.3</b>
<b>20. Intravenous hyperalimentation.</b> Patients who receive central or peripheral venous infusion of parenteral nutrition.	<b>2.8</b>
<b>21. Enteral feeding. Through gastric tube or other gastrointestinal route</b> Patients who receive enteral feeding through tubes, by any route of the gastrointestinal tract. Measurement of aspiration/retention included.	<b>1.3</b>
<b>SPECIFIC INTERVENTIONS</b>	
<b>22. Specific intervention(s) in the intensive care unit. Endotracheal intubation, insertion of pacemaker, cardioversion, endoscopies, emergency surgery in the past 24 h, gastric la vage. Routine interventions without direct consequences for the clinical condition of the patient, such as: X-rays, echography, electrocardiogram, dressing, or insertion of venous or arterial catheters, are not included.</b> Patients submitted to a diagnostic or therapeutic intervention listed above in the ICU. Specific procedures performed in the unit and which require active intervention of the staff can be considered in this item, including the insertion of venous or arterial catheters and spinal puncture. Procedures performed by the nurse, such as passing a relief or indwelling urinary catheter, gastric tube, a peripherally inserted central catheter (PICC), installation of intra-abdominal pressure, among others, that might be particular complex and require more nursing time for their execution can also be considered.	<b>2.8</b>
<b>23. Specific interventions outside the intensive care unit. Surgery or diagnostic procedures.</b> Patients who require diagnostic or therapeutic interventions performed outside the ICU. E.g.: tomography, radionuclide imaging, magnetic resonance, hemodynamic (take or pick up a patient), surgical procedures (take or pick up a patient), patient transfer to any hospitalization unit or discharge, and sending the body to the morgue.	<b>1.9</b>
<b>Observations:</b> The sub-items of item 1,4,6,7 and 8 are mutually exclusive as well as NORMAL, MORE THAN NORMAL and MUCH MORE THAN NORMAL. In the calculation of the total NAS, the greatest score obtained in the items 1, 4, 6, 7 and 8 in the 24 h period will be considered.	

the average was 96.2%. The median value of NAS recorded with the minimal standard deviation favour for a reliable value, reflecting the most suitable nurse-to-patient ratio of 0.68 (NAS score equal to 67.9). As reported in our data during the investigation's time, the planned staff reflected a NAS score equal to 0.61. Considering the gap within the scores, we could support a potential existing condition of chronic understaffing equal to 0.07 nurse for each patient. Working out this value for ten beds, we could affirm that during the period of this study, a value of 0.7 nurses were missing

for each shift. This speculation could be reflecting the right nurse staffing only if the occupancy rates were equal to 100%. However, during the study's period, it was  $85 \pm 13\%$ . As suggested by the literature (Guccione et al., 2004), the median NAS recorded should be calculated according to the real occupancy rates, keeping in mind that nurse staffing is routinely planned on the number of equipped beds rather than occupancy rates (Valentin et al., 2011). The median NAS of the present study (68.1) related to the occupancy rates (85%), results into a mean NAS/occupancy ratio of 57.8; in other

**Table 2**  
NAS score according to admission source.

Admission department	General Surgery	General Medicine	Emergency	Neurology	Cardiology	Haematology	From other ICUs transferred without ECMO	From other ICUs transferred on ECMO	p.value*
Age median - (IQR)	n = 1443* (55%) 69.0 (57.0–77.0)	n = 237 (9%) 70.0 (59.0–77.0)	n = 434 (17%) 56.7 (43.0–74.0)	n = 49 (2%) 65.8.0 (55.8–76.0)	n = 63 (2%) 67.0 (57.0–76.0)	n = 81 (3%) 58.0 (46.3–63.8)	n = 229 (9%) 39.0 (29.0–62.0)	n = 70 (3%) 44.5 (36.0–56.0)	<0.0001
0–10 years	n = 19 (1%) -	-	n = 2 (1%) -	-	-	n = 8 (10%) -	n = 2 (5%) -	n = 2 (5%) -	
11–18 years	n = 17 (1%) -	-	-	-	-	n = 11 (13%) -	n = 7 (5%) -	n = 7 (5%) -	
greater than 18 years	n = 1407 (98%) 66.8 (53.8–76.7)	n = 237 (100%) 70.1 (59.4–86.7)	n = 422 (99%) 74.3 (61.7–84.9)	n = 49 (100%) 70.2 (61.0–87.0)	n = 63 (100%) 73.2 (59.4–91.5)	n = 62 (77%) 76.5 (59.7–88.0)	n = 229 (100%) 76.8 (61.2–94.2)	n = 61 (90%) 101.8 (92.6–115.6)	<0.0001
NAS Admission day median - (IQR)	65.3 (55.9–74.5)	68.9 (61.1–77.2)	68.9 (61.5–76.4)	70.2 (64.3–76.9)	70.3 (59.0–81.4)	72.1 (62.2–80.5)	72.7 (61.8–79.6)	86.4 (81.6–96.4)	<0.0001
NAS ICU stay median - (IQR)	61.4 (51.9–72.3)	63.1 (54.4–74.7)	61.6 (51.2–71.8)	62.7 (56.2–73.6)	65.0 (52.2–74.2)	68.2 (59.2–80.0)	64.7 (52.5–76.7)	74.0 (59.0–87.8)	<0.0001
NAS before discharge day median - (IQR)	3 (3%)	6 (6%)	1 (1%)	1 (1%)	1 (1%)	5 (6%)	9 (9%)	70 (74%)	<0.0001
ECMO patients n(%)									

\* Kruskal-Wallis H test.

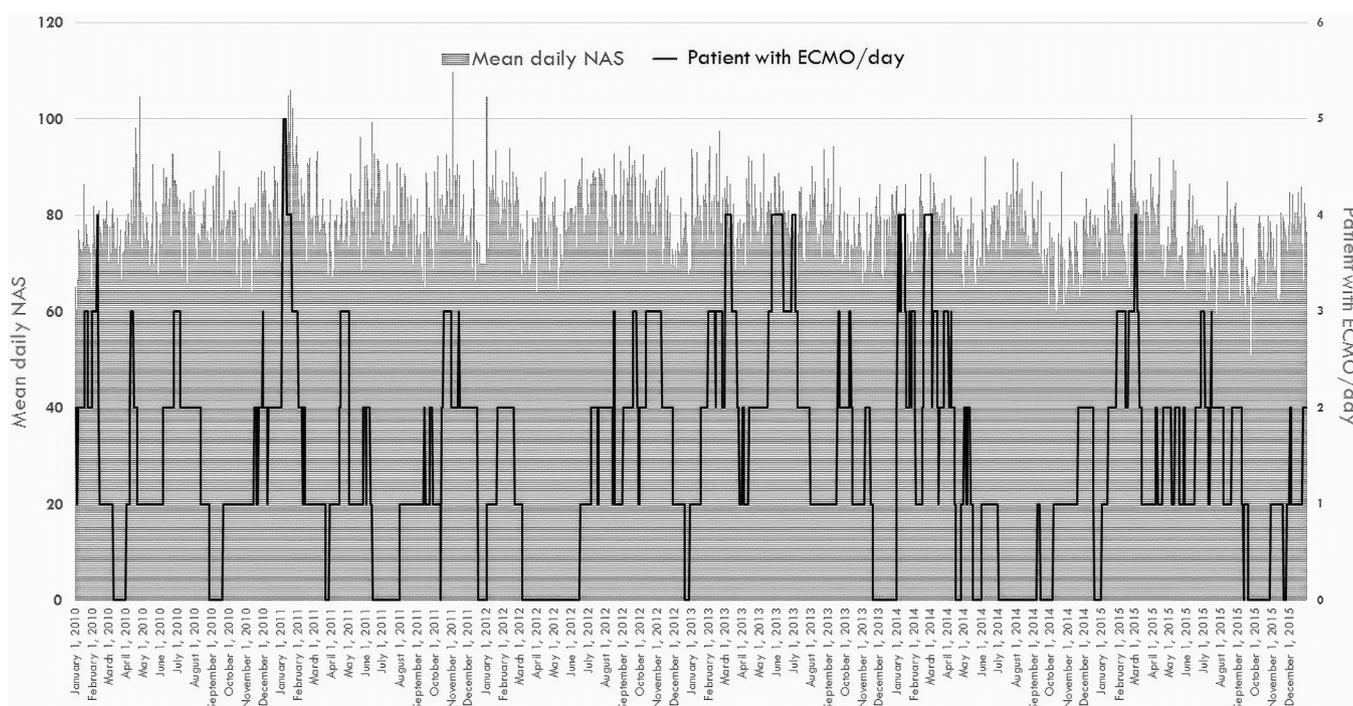
words, a nurse-to-patient ratio equal to 0.6. The nursing manpower available during this study was 0.6 (nurse-to-patient ratio). It was not adequate for the average nursing workload of the patients but well balanced when compared with the real bed occupancy rate. Accurate recording of NAS in critically ill patients, represents a crucial step in the evaluation of the most suitable nurse-to-patient ratio, but, at the same time, it should be always related in accordance with context aspects (Valentin et al., 2011). On day first, patients transferred from surgical units showed a lesser score (NAS 66.8 – IQR: 53.8–76.7) in comparison with others from medical and emergency departments, respectively 70.1 (IQR: 59.4–86.7) and 74.3 (IQR: 61.7–84.9). Understandably, the highest score on day first was recorded for patients transferred from out of hospital ICUs (76.8 – IQR: 61.2–94.2) and for patients transferred by our mobile ECMO team (101.8 – IQR: 92.6–115.6). However, it is useful to point out that the second highest score was collected by two different categories of patients: haematological and paediatric (76.5 – IQR 59.7–88.0). Possible explanations of this existing gap of 10% in the NAS (in comparison with the surgical patients), could be the intensive use of non-invasive mask ventilation (NIMV) to avoid endotracheal intubation (Villa et al., 2010; Bellani et al., 2016, 2017) and the population's age, mainly composed by paediatric patients. Apparently the patient's age doesn't played a key role in the process, in fact it showed a low correlation equal to  $r = -0.081$  ( $p = 0.0001$ ), but, in some reports, critically ill children require a greater nurse manpower to meet their specific needs (Debergh et al., 2012; Lucchini et al., 2014). Vice versa, lesser differences were recorded on discharge days, except for patients transferred to other ICUs. In accordance to our data, NAS has been also influenced by other elements: hospital length of stay ( $r = 0.27$ ), level of sedation measured by the RASS tool ( $r = -0.37$ ) and the SAPS 3 scoring system ( $r = 0.25$ ). Our findings may be strongly affected by the ECMO patients in some ways. Despite their minimal number in the whole population investigated (4%), their specific clinical features are totally unique when compared to standards ICU's patients. In the six studied years, the mean number of patients under ECMO support was 16. The volume of ECMO cases per year seems to be lower if compared to the recommendations of Barbaro et al. (2015). However, in the hospital setting of this study there is a respiratory ECMO unit (from which the data were gathered) and a cardiac ECMO unit, both led by the same Director. The annual volume of these two ICU's together, overcomes the minimum volume for every single hospital according to Barbaro et al. (2015). ECMO patients recorded a greater NAS score on day first (median 101 [IQR: 87–111]) and during the hospital stay (median 87 [IQR: 82–96]). Moreover, they were younger (median 49 [IQR: 38–59]), severely ill on the admission's day (SAPS 3: median 37 [IQR: 25–54]), requiring a longer sedation's plan (LOS' median RASS:  $-3$  [IQR:  $-4/-2$ ] Vs.  $-1$  [IQR:  $-2/0$ ]). As reported in literature, the ultimate nurse-to-patient ratio for ECMO patients should be a value between 0.75 and 1.5 (Combes et al., 2014; Lucchini et al., 2014).

ECMO patients are usually unstable and nursing care may be more challenging and hazardous due to precarious oxygenation, anticoagulation and possible incidental decannulation. These activities result in a greater presence of the nurse at the bedside (NAS section – 1. Monitoring and titration – subitem 1b, score: 12.1 or 1c, score: 19.6). Hygienic care in ECMO patients may require the presence of two or more nurses (NAS section – 4. Hygiene procedures – subitem 4b, score: 16.5). Thus, the sedation status should be carefully assessed during nursing care. Moreover the correct sedation level could become difficult to achieve, because of drug “kidnapping” in the ECMO membrane. In veno-venous ECMO patients, an inadequate plan may lead also to oxygen consumption increase, elevation in cardiac output, and subsequent arterial desaturation (Redaelli et al., 2016). In spontaneous

**Table 3**  
NAS score according to clinical characteristics and level of care.

	ECMO patients n = 95 (4%) median (IQR)	Other ICU patients n = 1670 (64%) median (IQR)	Elective Post-operative patients n = 841 (32%) median (IQR)	p.value <sup>*</sup>
NAS (admission day)	101.2 (86.5–111.1)	74.4 (61.7–86.9)	61.7 (51.2–73.7)	<0.0001
Median NAS	87.2 (82.1–95.6)	69.4 (62.0–76.4)	63.1 (53.0–74.5)	<0.0001
NAS (discharge day)	74.2 (57.9–88.4)	62.3 (52.8–72.7)	61.6 (51.4–73.5)	<0.0001
Age (years)	49.0 (38.0–58.5)	66.0 (50.0–76.0)	70.0 (58.0–78.0)	<0.0001
LOS (days)	26.0 (14.3–43.5)	4.0 (2.0–7.0)	1.0 (1.0–1.0)	<0.0001
SAPS 3	37.0 (27.3–54.0)	36 (26–50)	23.0 (17.0–34.0)	0.068
median RASS during ICU stay	– 3 (–4/–2)	– 1 (–2/–0)	0 (–1/0)	<0.0001
<b>Spearman correlation:</b>				
NAS/Age	r = –0.04 (p = 0.649)	r = –0.09 (p < 0.0001)	r = –0.07 (p < 0.0001)	
NAS/LOS	r = –0.04 (p = 0.68)	r = 0.33 (p < 0.0001)	r = 0.32 (p < 0.0001)	
NAS/SAPS 3	r = –0.03 (p = 0.81)	r = 0.16 (p < 0.0001)	r = 0.22 (p < 0.0001)	
NAS/RASS	r = –0.50 (p < 0.0001)	r = –0.40 (p < 0.0001)	r = –0.34 (p < 0.0001)	

<sup>\*</sup> Kruskal-Wallis H test.



**Fig. 1.** Average daily NAS and number of ECMO patients per day.

breathing patients, mobilisation and painful stimulation may increase their work of breathing, leading to a critical minute ventilation (Redaelli et al., 2016). Daily nursing in such patients is also important to evaluate bleeding and vascular access, but these tasks are more difficult (Lucchini et al., 2018a,b). The exit cannula' site requires a daily monitoring, like any other vascular access, to early detect and prevent any signs of infection, bleeding and devices dislocation. Nursing workload can increase even for continuous monitoring of extracorporeal circuit and monitoring gas exchange (extra blood analyses). Circuit monitoring is essential to understand when the ECMO circuit needs to be replaced (NAS section – 8. Administrative and managerial tasks – subitem 8b, score: 23.2 or 8c, score: 30.0). A circuit change requires ECMO support stopping for a brief period of time while the circuit is exchanged. If the patient is very dependent on ECMO for support, they may deteriorate dramatically. Furthermore increasing in nursing workload may reflect different factors: longer periods of sedation and muscle paralysis (Bellani et al., 2016), prone position therapy (NAS section – 6. Mobilization and positioning – subitem – 6c,

score: 17.0) (Guerin et al., 2018; Lucchini et al., 2018a,b), use of continuous veno-venous hemofiltration support (NAS section – 16. Renal support, score: 7.6) (Chen et al., 2014), implementing early mobilisation protocols (Wells et al., 2018) and involving patients' relatives in the process of recovery. Any other nursing intervention that can not be directly allocated to any NAS items, can be measured as greater presence of the nurse at the bedside (NAS section – 1. Monitoring and titration).

In our region, the winter season is characterised by a pandemic-flu period, this has led to an increased presence of ECMO patients (as shown in Table 2) and simultaneously has restricted the flexibility of the available resources. Data collected in our study showed how the presence of ECMO patients is able to affect the average NAS ( $r = 0.176 - p < 0.0001$ ). Apparently just one ECMO patient does not affect the nursing workload considerably, but two or more of them in a total number of ten patients, is able to increase the percentage in the nursing workload, from 2 to 7%. In other words, for a ten bedded ICU, it means the need of an extra nurse presence of 0.7 in the ICU's staff. In order to achieve this staff

requirement, daily nurses' presence (12 hour shift) was implemented, especially during the pandemic time of the year, together with the adjustment of two bed spaces from post-operative to intensive care bed units. Dedicated funds from the budget were committed for the extra nursing staff to keep at least, an overall nurse-to-patient ratio equal to 0.6, with a nurse-to-patient ratio of 1:1 for ECMO patients. During the seasonal pandemic time of the year, all the surgical patients requiring post-surgery ICU's recovery were shifted to different ICUs within the Trust.

### Implications for future research

This study showed that the nursing workload for ECMO patients is higher than other categories of ICU patients. Our work should be considered a call to action for other research groups to join forces and set up a multicentre trial to better investigate what factors of ECMO patients can affect the nursing workload and have an impact on resource allocation.

### Limitations

This is a retrospective single-centre study. Conclusions may have some bias related to the individual centre. Moreover the analysis was performed on a population distinguished by a collection of NAS and other scores already taken. However, the major issue during the assessment process was the omission of items (leading to an underscoring of higher and more rewarded NAS scores). We do not believe that a prospective audit would have strikingly changed our results. Some specific characteristics of a given patient could have influenced the results, although only to a limited extent given the number of patients included (Palese et al., 2016).

### Conclusions

Nursing workload in ICU performing as an ECMO referral centre may be affected by the number of patients treated simultaneously by ECMO support. NAS values recorded in our study support and reinforce the available recommendations (Combes et al., 2014) regarding the suitable nurse staffing for an ECMO centre. During ECMO, the nurse-to-patient ratio should be at least 1:1 (one nurse for up to one patient receiving ECMO where necessary based on unit staffing standards) depending on local or national regulations and organisation. In accordance to our data, NAS has been also influenced by other elements: hospital length of stay, level of sedation measured by the RASS tool and the SAPS 3 scoring system.

Lastly, findings from this study support the current evidence about benefits of centralising ECMO patients in dedicated referral centres, distinguished by a dedicated medical team, technology and a dedicated nurse staffing in every clinical and management aspect.

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### Authors' contribution

AL, SE, CDF, CG, AM, PR, RF, and GF conception and design of the study, manuscript writing and final approval. AL, SE, CDF, CG, AM, PR: data collection and analysis. AL, SE, RF: statistical analysis. AL,

CDF, GF, CG, AM, PR e RF manuscript writing, and final approval of the manuscript. All authors have read and approved the final manuscript.

### Declaration of Competing Interest

The authors declare they have no conflict of interest.

### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.iccn.2019.07.008>.

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