Chapter 1
Monitoring Patients: What's New in Intensive Care Setting?

Matteo Manici and Claudio Torbinio

1.1 Introduction

Monitoring ("to monitor") is a term that involves the observation, actions, measuring, and understanding of many human activities in time. The origin of the word "monitoring" comes from the Latin *monitor*, *-oris*, derived from the verb *monēre* (literally, to warn) and means a continuous or repeated observation, measurement, and evaluation of health and/or environmental or technical data for defined purposes, in accordance with predetermined programs in space and time. Monitoring can be implemented using comparable methods for the detection and collection of data [1]. The term originated in industrial environment, to indicate the continuous control of an operating machine, with appropriate instruments which measure some characteristic parameters (speed, consumption, production, etc.). The original meaning was later expanded: from the machine to the whole process, for an operational structure, and also human resources. Monitoring is widespread used in technical and in social sciences, with the general meaning of "data collections" significant for context.

Historically, monitoring started as a physiological measurement problem (Table 1.1) and probably will end up as an overall

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Table 1.1 Short history of physiological data measurements [2]

When	*Who*	What
1625	*Santorio*	Measurement of body temperature with spirit thermometer. Timing pulse with pendulum. Principles were established by Galileo. These results were ignored
1707	*Sir John Foyer*	Published pulse watch
1852	*Ludwig Taube*	Course of patient's fever measurement. At this time temperature, pulse rate, and respiratory rate had become standard vital signs
1896	*Scipione Riva-Rocci*	Introduced the sphygmomanometer (blood pressure cuff)
1900	*Nikolaj Sergeevič Korotkov*	Applied the cuff with the stethoscope (developed by Rene Laennec—French physician) to measure systolic and diastolic blood pressures
1900	*Harvey Cushing*	Applied routine blood pressure in operating rooms
1903	*Willem Einthoven*	Devised the string galvanometer to measure ECG (Nobel Prize 1924)
1939–1945		World War II: development of transducers
1948–1950	*George Ludwig*, *Ian Donald*, *Douglass Howry*, *and Joseph Holmes*	Pioneers of ultrasounds in health science
1950		The ICU's were established to meet the increasing demands for more acute and intensive care required by patients with complex disorders
1953		Danish patients with poliomyelitis received invasive mechanical ventilation

Table 1.1 (continued)

When	*Who*	What
1963	*Hughes W. Day*	Reported that treatment of post-myocardial infarction patients in a coronary care unit reduced mortality by 60%
1968	*Maloney*	Suggested that having the nurse record vital signs every few hours was "only to assure regular nurse-patient contact"
Early 1970s		Bedside monitors built around bouncing balls or conventional oscilloscope
1972	*Takuo Aoyagi*	Developed a pulse oximeter based on the ratio of red to infrared light absorption in blood. After obtained an US patent, oximetry became clinically feasible
1973	*Jeremy Swan and William Ganz*	Pulmonary artery balloon flotation catheter starts advanced hemodynamic study
1990s		Computer-based patient monitors; systems with database functions, report-generation systems, and some decision-making capabilities

assessment of intensive care unit (ICU) patient. This chapter has an introductory function for the first section: the concept of generality of instrumental monitoring, the monitoring carried out through applying scales at patient's bed, to propose a new monitoring model for ICU patient.

ICUs are very different, such as medical and surgical wards, because of different staff availability (especially nurses) and expertise, skills, technologies, and environments. Monitoring activity involves the entire ICU staff (nurses, physician, respiratory therapists and rehabilitation therapists, dietitians) and is based on different operational models implemented in several countries around the world. Nurses, wherever present 24 h a day, often act as liaison between the various staff components, ensuring security, continuity, and harmony and coordinating and communicating all aspects of treatment and care the patient needs. Nurses also provide continuous monitoring and caring for patients and equipment and for their interactions [3].

1.2 Instrumental Monitoring

Technology is extremely pervasive and is continuously increasing in ICU. It is commonly used in a multitude of tools for monitoring and supporting patient's vital functions: the brain, lung, heart, and kidney. The widespread use of electronic monitoring and support to vital function has probably helped to prevent errors and to improve outcomes [4].

The monitoring tools are able to detect multiple parameters, such as continuous electrocardiogram (ECG), end-tidal carbon dioxide $(EtCO)_2$, various measurements of peripheral oxygen saturation (SpO_2), cardiac output, and intracranial and cerebral perfusion pressure. The supporting devices can affect the respiratory system (noninvasive mechanical ventilation), circulatory (pacemakers, intra-aortic balloon pump, ventricular devices), cardiorespiratory (extracorporeal membrane oxygenation—ECMO), and kidney (continuous renal replacement therapy (CRRT) and slow low-efficiency daily dialysis (SLEDD)). All these supporting systems contextually also provide monitoring parameters (e.g., the ventilator). Understanding the functions of the devices commonly used in ICU can help in caring for patients in critical conditions [5].

The monitoring technique in intensive care has risks and benefits. Intensive monitoring provides a high data value and information, but it can increase some risks of complications.

For example, intensive monitoring could be useful in acute medical interventions aiming to maintain the essential variables within a narrow physiological range and improve the outcome in people with acute stroke [6] (Fig. 1.1).

At the same time, continuous monitoring can increase unnecessary medical interventions and limit patient's mobility, thus increasing the risk of complications related to forced immobility as bedsores, stasis pneumonia, deep vein thrombosis (DVT), thromboembolism (TE), and pain [7].

All recorded data must be evaluated in the clinical context. The value of data must be compared with the accuracy of the instrument, its need for calibration, artifacts, and fictitious events (such

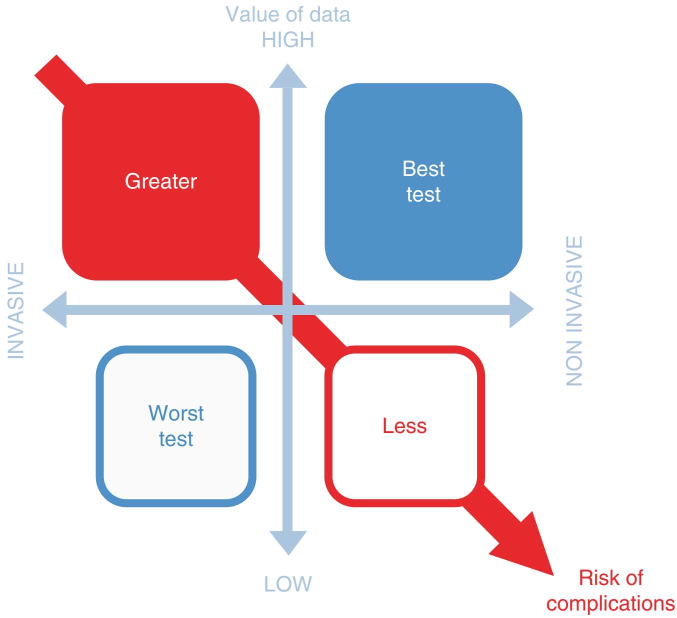

Fig. 1.1 Conceptual framework-related value of data

as a cough during ventilation). As told it is essential to treat patients and their disease instead of numbers. All monitored parameters must be considered in relation to the disease as the best method to treat the same.

In medical literature there are many studies concerning the false alarm rates in the critical patient monitoring. These studies show more than 90% of ICU alarms are false flags. In many cases, these are caused by measurement errors and by patient's movement. The majority of ICU alarms have no real clinical impact on patient care [8].

A too sensitive monitoring can create "panic" within the team. Staff alarm fatigue can determine inadequate and routine alarm settings. Alarms settings should be tailored on patients individual clinical needs and targets [9]. However, the biggest danger is given by turning off the alarms without understanding events actually occurring to patients. Alarm management is a part of the skills that intensive care staff need to learn at the beginning of their professional careers.

1.3 Monitoring and Scales

Through the use of a variety of assessment scales (mono-dimensional or multidimensional, according to the complexity of the construct they want to observe), it is possible to obtain measures of many functional states that cannot be described by any instrumental monitoring systems.

Some aspects have been carefully studied by many authors such as pain, sedation, delirium, and state of consciousness. Other authors made comparisons between tools to determine their adequacy in psychometric characteristics, becoming recommended in international guidelines [10].

An example of the use of scales (and their variations) is represented by functional evaluation. ICU patients frequently experience prolonged immobilization and tend to lose their functional ability. In these patients functional skills assessment during ICU stay and prior ICU discharge becomes crucial to prevent damage from immobility. Many scales have been used for the evaluation of functional abilities, impairments, and/or patients' disabilities. The extent of these outcomes includes different measurement scales. The choice of the right one will depend on the specific cohort of patients, the diagnosis, the stage of rehabilitation, and the available measure sets [11]. These scales are summarized in Table 1.2. Their applicability in ICU environments (including the follow-up period) is indicated in the last column.

1.4 Bedside Monitoring: An Overview

The ICU monitoring is a component of critical area skill set, featuring as neurological monitoring, respiratory, hemodynamic, renal, hepatic, and nutritional. Each function can be both assessed using validated tools and/or instrumental monitoring [12–14].

The rating scales are mostly developed in the assessment of psychosocial functions (neurologic evaluation, pain, sedation, and delirium) and the instrumental monitoring for detection of biological parameters (respiration, hemodynamics, temperature, and metabolism).

The main monitoring variables "to read and feel" are summarized in Table 1.3.

A useful example of the effectiveness of the interpretation of monitoring takes us outside the ICU with Early Warning Score (EWS) in the National Early Warning Score (NEWS) variants and Modified Early Warning Score (MEWS) (Table 1.4). The basic

Table 1.2 Functional assessment scales in the ICUs [11], modified with permission

Scale	Description	Interpretation	Applicability in ICU setting
Functional Status Score for the ICU (FSS-ICU)	Consists of three preambulation categories (rolling, supine to sit transfer, and unsupported sitting) and two ambulation categories (sit to stand transfers and ambulation)	• Rating: 1 (total dependent assistance) to 7 (complete independence) scale • Score: 0–35 (0 score: unable to perform a task due to physical limitations or medical status)	++
4P questionnaire	Evaluates physical and psychosocial problems following ICU recovery	• 4P: patients, physical, psychosocial, and problems • 4P comprises 53 items: 16 physical items, 26 psychosocial items, and 11 follow-up ICU care items, scored on a 5-point Likert scale measuring level of agreement from "strongly agree" to "do not agree at all"	++

Physical Function ICU Test (PFIT)	Used with critically ill patients who may not be able to mobilize away from the bedside, employing four domains	• Amount of assistance for sit to stand, rated from 0 (no physical assistance required) to 3 (assistance of three people required) • Strength for shoulder flexion and knee extension (rated on the Oxford Muscle Test Scale) • Marching in place (number of steps taken and the time required to complete these steps) • An upper extremity endurance task of arm elevation to 90° shoulder flexion (number of times both upper extremities are lifted above 90° of shoulder flexion)	++

(continued)

Table 1.2 (continued)

Scale	Description	Interpretation	Applicability in ICU setting
Modified Rankin Scale (mRS)	Quantifies independence and disability, with a scale of 6 grades (0–5)	• 0, no symptoms • 1, no significant disability despite symptoms • 2, slight disability • 3, moderate disability • 4, moderately severe disability • 5, severe disability	+
Glasgow Outcome Scale (GOS)	Provides a global assessment of function (see text for modified GOS scales)	• Score 1: good recovery • Score 2: moderate disability • Score 3: severe disability • Score 4 vegetative state • Score 5: death	+
Karnofsky Performance Scale Index	A descriptive, ordinal scale that ranges from 100 (good health) to 0 (dead) and emphasizes physical performance and dependency	• Karnofsky index of 70–100: a favorable functional outcome measure	±

Barthel Index (BI)	It measures the capacity to perform ten basic activities of daily living self-care (feeding, grooming, bathing, dressing, bowel and bladder care, and toilet use) and mobility (ambulation, transfers, and stair climbing)	Scoring ranges from 0 (totally dependent) to 100 (totally independent) • BI index score >90: minimal or no disability • BI index 55–90: moderate disability • BI index <55: severe disability	±
Disability Rating Scale (DRS)	A common outcome measure of impairment, disability, and handicap; the scale is intended to assess accurately general functional changes over the course of recovery	• Impairment ratings: "eye opening," "communication ability," and "motor response" • Level of disability: ability for "feeding," "toileting" and "grooming" • Handicap: "level of functioning" and "employability" • Rating for each functioning area: scale of 0 to either 3 or 5 • Maximum score (29): extreme vegetative state • Lowest score (0): a person without disability	±

Table 1.3 Synoptic table of principal monitoring

Monitoring	Main technological devices	Main assessment scale
Neurological	• Electroencephalography • ICP (intracranial pressure) and CPP (central perfusion pressure) • Brain tissue oxygen monitoring [15] • Cerebral microdialysis [16]	• GCS (Glasgow coma scale) • FOUR (Full Outline of UnResponsiveness) • Pupillary reactivity [15]
Pain		• NRS (Numerical Rating Scale) • NRS-V (NRS-Visual horizontal) • BPS (Behavioral Pain Scale) • BPS-NI (Behavioral Pain Scale Non-Intubated) CPOT (Critical-Care Pain Observation Tool) [17]
Agitation (sedation)	• BIS (bispectral index) [18]	• SAS (Sedation-Agitation Scale) • RASS (Richmond Agitation-Sedation Scale) [17]
Delirium		• CAM-ICU (Confusion Assessment Method-ICU) • ICDSC (Intensive Care Delirium Screening Checklist) [17]

Respiratory and ventilator	• Basic respiratory system mechanics • Static compliance of the respiratory system • Resistance of the respiratory system • Dynamic hyperinflation • Gas exchange (monitoring oxygenation, arterial oximetry, efficacy of oxygen exchange, monitoring carbon dioxide, assessment of $PaCO_2$, dead space ventilation and PCO_2) [19] • Graphic curve ventilator monitoring [20]
Traditional hemodynamic	• Cardiac ECG (HR, HR variability, arrhythmias, ST monitoring) • IBP (invasive blood pressure) • NIBP (noninvasive BP) • CVP (central venous pressure) • SwGa measurement (PAP, PW, SV, CO, indexed value, etc.) [19]
Central hemodynamic monitoring	• Macrocirculation monitoring (pulse contour analysis, Vigileo/FloTrac system, LiDCO, the PiCCO system, esophageal Doppler, thoracic electrical bioimpedance, echocardiography) [19]

(continued)

Table 1.3 (continued)

Monitoring	Main technological devices	Main assessment scale
Peripheral hemodynamic-tissue perfusion	• Microcirculation monitoring • Gastric tonometry and sublingual capnography • Mixed venous or central venous saturation (SvO_2 and oxygen extraction, interpreting SvO_2, $ScvO_2$, and perfusion) • Lactate clearance • Venous-to-arterial CO_2 gradient (CO_2 production and transport physiology, determinants of $P(v–a)CO_2$, $P(v–a)CO_2$ increase, and clinical hypoperfusion) [19] • IAP (intra-abdominal pressure) and APP (abdominal perfusion pressure)	
Temperature	• Accurate measurement in the pulmonary artery, distal esophagus, tympanic membrane, bladder, or nasopharynx [19]	
Nutritional and metabolic care	• Protein and energy delivery for the prevention of protein-energy deficit • Glycemia and insulin therapy for optimized glycemic control [19]	• NRI (Nutritional Risk Index) • GNRI (Geriatric Nutritional Risk Index) • SGA (Subjective Global Assessment) MNA-SF (Mini Nutritional Assessment-Screening Form) • MUST (Malnutrition Universal Screening Tool) • NRS 2002 (Nutritional Risk Screening 2002) [21]

Table 1.4 NEWS and MEWS comparison

	NEWS (National Early Warning System)							MEWS (Modified Early Warning System)						
Physiological parameters	3	2	1	0	1	2	3	3	2	1	0	1	2	3
Respiration rate (breath/min)	≤8		9 11	12 20		21 24	≥25		≤8		9 14	15 20	21 29	≥30
Oxygen saturation (%)	≤90	91–93	94 95	≥96										
Supplemental oxygen		Yes		No										
Temperature (°C)	≤35.0		35.1 36.0	36.1 38.0	38.1 39.0	≥39.1			≤35.0	35.1 36	36.1 38	38.1 38.5	≥38.6	
Systolic BP (mmHg)	≤90	91 100	101 110	111 219			≥220	≤70	71 80	81 100	101 199		≥200	
Heart rate (beat/min)	≤40		41 50	51 90	91 110	111 130	≥131		≤40	40 50	51 100	101 110	111 129	≥129
Level of consciousness (AVPU)				A			V, P o U	U	P	V	A		New Agit. Conf.	
Hourly urine for 2 h (mL/h)								≤10	11 30	31 45				

0–4—low level of clinical risk: monitoring
5–6—medium level of clinical risk: call physician
≥7 or single item at level 3—high level of clinical risk: call emergency team

principle is the collection of common physical parameters and variables in a score that allows a fast and shared evaluation of clinical status. In hospitalized patients, addressing the deterioration of physiological functions before they precipitate and to define the intensity of required care can be helpful. In the community, the numerical values expressed by NEWS provide a clear indication of the severity level and help to find the limit for referral to the emergency department and urgent.

In general, the NEWS score provides a universal standard for the evaluation of the clinical course, with the sole exception of obstetrical and pediatric cases, and end of life care [22]. The comparison of the two instruments is reported in Table 1.4.

1.5 A New Monitoring Model

Which point of view can we provide with the monitoring for an interpretation pace with the expectations of nurses who study, who approach, and who are eventually working in intensive care? What we propose with this text is a more holistic view of the event "monitoring": a nursing activity that concerns first the person as a whole and, then, individual organ parameters and vital signs.

Monitoring can be defined in a conceptual area bounded by the level of invasiveness and objectivity of the systems that we use in the "measurement." Increasing the level of invasiveness and objectivity of the measures will also increase the precision level of the measured variables. Collected information must be sufficient and necessary to determine the diagnosis, the performance of the clinical status, and the response to therapies, but, the collection of unnecessary data (such as the execution of ECG 12 times a day in people without cardiac problems, performing unnecessary blood tests, or even the advanced hemodynamic monitoring in patients with only slightly altered parameters) worsens costs without improving outcomes. In a context of limited resources, the selection of the right level of monitoring should be based on proven systems that maximize the cost-benefit ratio [23].

The concept can be expressed in a diagram (Fig. 1.2) in which the operator is bounded by increasing levels of invasiveness and objectivity of the measures, resulting in three different monitoring levels:

- Level 1: intuitive observational monitoring
- Level 2: discontinuous monitoring
- Level 3: continuous monitoring

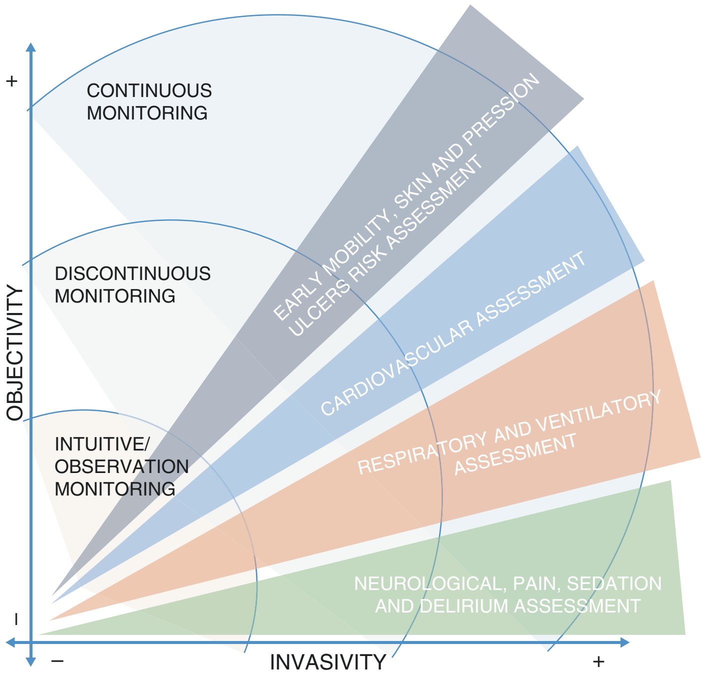

Fig. 1.2 The MAGIS (acronym of the initials of authors' names) model of intensive care nursing monitoring

The effective observation of hospitalized patients is the first step to identify the patient's concerns and the effectiveness of care management. In all contexts, it is vital for nurses to understand the dataset collected, for a positive impact on outcome of patients through the prevention of problems, which otherwise can drive to acute illness, ICU readmission, or death [24].

Poor technology leads to nurse's feelings play an important role in the perception of patient's deterioration, and vital parameters are used to support the "gut" feelings [25], that is, highly complex and influenced by many factor process, including the experience and preparation of nurses as well as their ability to relate to the medical staff.

There is a lot of difference in the world regarding "ICU numbers": the number of ICU beds for 100 hospital beds or for 100,000 people and technologies and health staff as well as the level of education [26]. But feeling and observation are available for all.

The evaluation of EWS facilitated the early identification of a critical condition. Nurses are called to act professionally and responsibly, to understand the meaning of the observations collected on patients and recorded during time. With a partnership approach to problem-solving, nurses can be effective in communicating with the multidisciplinary team and in bringing the most appropriate care [24, 27].

Discontinuous measurements are often carried out with the rating scales. Continuous ones are instead often obtained with electronic instruments appropriately alerted. These are a lot of tools able to ensure the safety and reliability of the monitoring that arises at the base of support of the ICU quality.

We believe that the nurse who approaches in intensive care cannot think in terms of machine/scale dualism as happened for many years. The MAGIS model (Fig. 1.2) is the operationalization of monitoring construct shown in this text. It suggests a systematic approach to monitoring that begins by insights and observation of clinical variables and appearance of the patient and deepens the clinical trial on rating scales and instrumental monitoring.

Monitoring is a dynamic process, a set of details that, correctly linked and interpreted, describe the entirety of the person in relation to his state of health in the moment of observation and over time, through the evolution of trends. The multimodal monitoring offered by different equipments require high levels of expertise within nursing staff to find answers that are not wasteful and respect the proper use of resources in terms of cost/effectiveness.

In conclusion, the new monitoring technologies are to be built up and have to demonstrate a positive impact on the result before being used. We believe that there is no easy answer to this question. Most hospital administrators require outcome data before purchasing any new and expensive technology. This approach, however, could delay application of useful technologies.

There are few studies that have analyzed the impact of monitoring on results. For example, the oximeter has shown no impact on patients' outcomes [28], and the role of intracranial pressure routine monitoring in comatose patients with acute trauma fails to provide evidence in support of the operation [29]. Despite of these results, those systems are considered essential in monitoring.

A more reflective evaluation of clinical indications and the training of doctors in the area of Swan-Ganz catheter and hemodynamic management would have avoided many patients the unnecessary placement of the cardiac catheter-related damage [30].

Daily challenges will come from deep knowledge of monitoring technologies and appropriate choice according to patient's condition, available resources, and staff expertise.

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