INTRODUCTION

Risk predictors and scoring systems are commonly used in medicine to provide a reliable and objective estimation of disease prognosis, probability of adverse events and outcome. Furthermore, they were designed to classify severity of illness or the course of diagnostic and therapeutic interventions and to perform risk stratification for scientific studies in a standardized way ***(Vincent et al., 2010)***.

In quality management and cost control, scoring systems and predictors are used for risk adjustment and evaluation of care performance ***(Lubin, 2006)***.

Different scoring systems and classifications are available to stratify perioperative risk and adverse events in anesthesia. An increasing interest in risk-adjusted outcome studies led to the modeling and validation of different prognostic systems for postoperative morbidity, mortality and length of stay ***(Kramer et al., 2014)***.

There is also multiple scoring systems for evaluation of risks and benefits for different body systems e.g. (cardiovascular system, neurological system, liver and hematological diseases). Furthermore, there are scoring-systems for special events, such as difficult laryngoscopy or postoperative nausea and vomiting ***(Kramer et al., 2014)***.

Severity scoring systems in the intensive care unit have been developed in response to an increased emphasis on the evaluation and monitoring of health care services. There are four major purposes of severity-of-illness scoring systems. First, scoring systems are used in clinical trials for matching. Second, scoring systems are used to quantify severity of illness for administrative decisions such as resource allocation. Third, scoring systems assess intensive care unit (ICU) performance and compare the quality of care. Fourth, scoring systems are used to assess the prognosis of individual patients ***(Kuzniewicz et al., 2008)***.

Varity of ICU scoring systems are available and numerous classifications can be used e.g. (adult and pediatric ICU scoring system). The most frequently used generic severity indices in ICUs are Acute Physiology and Chronic Health Evaluation (APACHE) II, the Simplified Acute Physiology Score (SAPS), the Mortality Probability Model (MPM), the Multiple Organ Dysfunction Score (MODS) and Therapeutic Intervention Scoring System (TISS). Four of these five are physiology-based; only TISS is service intensity based ***(Vasilevskis et al., 2009)***.

Pain is a frequently experienced problem in critically ill patients in the ICU and postoperative practice. Pain may increase morbidity and mortality and may decrease the comfort of patients and health-related quality of life. The adequate use

of analgesics and sedatives therefore may decrease morbidity and mortality ***(Taylor, 2010)***.

The use of scoring systems for pain severity and sedation depth and the implementation of protocols increase with a more patient-oriented regime for analgesia and sedation. Currently, a trend is observed away from a hypnosisbased approach and toward an analgesia-based approach. Although these changes may improve pain and sedation practice, further efforts are needed for widespread implementation of pain scoring systems and analgesia protocols ***(Martin et al., 2012)***.

There are many available pain scales, such as the Numerical Rating Scale (NRS) and the Visual Analog Scale (VAS) which have been validated for acute pain only and not in mechanically ventilated patients in the ICU. The Behavioral Pain Scale (BPS) was developed specifically for measuring the severity of pain in sedated, mechanically ventilated, unresponsive patients in ICU, but this pain scale is still not generally accepted for routine Use ***(Dijkers, 2010)***.

AIM OF THE ESSAY

The aim of this essay is to describe common risk indices and scoring systems in anesthesia, intensive care and pain management practice and to point out their possible benefits and limitations.

CHAPTER1: ICU SCORING SYSTEMS

Patients are admitted to an ICU because they are suffering from an actual or potential life threatening condition. Although it is true that most patients admitted are in a serious condition some patients are admitted as a precautionary measure. Various factors have been shown to increase the risk of in-hospital mortality after admission to ICU, including increasing age and severity of acute illness, certain pre-existing medical conditions (e.g. malignancy, immune-suppression, and requirement for renal replacement therapy), emergency admission to ICU and the services the hospital itself delivers ***(Suter et al., 2006)***.

Before the 1980s, there were no scoring systems applicable to critical care populations which would allow outcomes from different critical care units to be compared. Since then, many scoring systems have been developed. Predictive scoring systems have been developed to measure the severity of disease and the prognosis of patients in the ICU. Such measurements are helpful for clinical decision making, standardizing research, and comparing the quality of patient care across ICUs ***(Bouch & Thompson, 2008)***.

Scoring systems in ICU differ between adult and children. Scoring systems used in critically ill adult patients can broadly be divided into scores that assess disease severity on

admission and use it to predict outcome (for example, APACHE, SAPS, MPM, scores that assess the presence and severity of organ dysfunction (for example, MODS, the Logistic Organ Dysfunction System (LODS), Sequential Organ Failure Assessment (SOFA) score), and scores that assess nursing workload use (for example, TISS) ***(Vincent & Moreno 2010)***.

1) Adult scoring systems

I) Acute Physiology and Chronic Health Evaluation (APACHE)

One of the most well-received generic severity measures based upon clinical data is the APACHE series, which calculates the probability of death independent of diagnosis. There are already four versions of this measure: APACHE I, II, III and IV ***(Kramer et al., 2014).***

a- The APACHE I system

The original APACHE scoring system was developed at the George Washington University Medical Centre in 1981 as a way to measure disease severity. It consisted of two parts: the APS (acute physiology score) representing the degree of acute illness and the CHE (chronic health evaluation) indicating physiological reserve before the acute illness ***(Knaws et al., 2006)***.

The APS composed of 34 variables (neurologic, cardiovascular, respiratory, renal, gastrointestinal, metabolic, and hematologic), they were selected and relative weights (0-4) were assigned to the variables according to the clinicians' clinical experience. The worst value of each variable within the first 32 hr after admission was used ***(Vincent & Moreno, 2010).***

b- The APACHE II system

The APACHE II system (Table1) was developed in 1985 and incorporated important modifications. The number of APS variables was reduced from 34 to only 12 through multivariate analysis of a large database. So, infrequently measured (e.g. osmolality) and redundant (e.g. BUN) variables were eliminated. In addition, the weights of variables were modified according to their statistical correlation to hospital mortality. The GCS was given an increased weight of 12 and ARF was double-weighted with a maximum score of 8. The most abnormal APS values within the first 24 hr of ICU admission were used. The patients were given a specific diagnosis according to the principal reason for ICU admission. Again, CHE points were assigned for only 7 organ system dysfunctions. Nonoperative and emergency surgeries were given additional weights and age was incorporated into the APACHE II score. The total maximum score is 71 ***(Bouch et al., 2008)***.

The APACHE II severity score has shown a good calibration (the probability of death of patient population) and discriminatory (the probability of individual patient death) value across a range of disease processes, and remains the most commonly used international severity scoring system worldwide ***(Zimmerman et al., 2006)*.**

The ***limitations*** of the APACHE system are: first, APACHE II underestimates the likelihood of death in patients who are transferred to the ICU after relative stabilization, as it uses ICU data only and does not account for prior treatment/ resuscitation. Second, APACHE II is inferior to the Trauma Injury Severity Score (TRISS) in predicting mortality in injured patients due to the absence of an anatomical component in the APACHE system. APACHE II also has been criticized because it lacks validity in certain types of patients, such as burn and CABG patients ***(Manganaro & Stark, 2010)*.**

Chronic Health Points:

If the patient has a history of severe organ system insufficiency or is immune-compromised as defined below, assign points as follows:

- 5 points for non-operative or emergency postoperative patients.
- 2 points for elective postoperative patients.

Organ insufficiency or immune-compromised state must have been evident prior to this hospital admission and conform to the following criteria:

- **Liver** – biopsy proven cirrhosis and documented portal hypertension; episodes of past upper GI bleeding attributed to portal hypertension; or prior episodes of hepatic failure/encephalopathy/coma.
- **Cardiovascular** – (NYHA) Class IV.
- **Respiratory** – Chronic restrictive, obstructive, or vascular disease resulting in severe exercise restriction (i.e., unable to climb stairs or perform household duties; or documented chronic hypoxia, hypercapnia, secondary polycythemia, severe pulmonary hypertension (>40 mmHg), or respirator dependency.
- **Renal** – receiving chronic dialysis.
- **Immune-compromised** – the patient has received therapy that suppresses resistance to infection (e.g., immune-suppression, chemotherapy, radiation, long term or recent high dose steroids, or has a disease that is sufficiently advanced to suppress resistance to infection, e.g., leukemia, lymphoma, Acquired Immunodeficiency Syndrome (AIDS).

(Vincent & Moreno, 2010)

APACHE II continues to be used as a valid severity-of-illness measurement, but its mortality predictions are no longer valid because the case-mix adjustment is inadequate, and mortality is severely over-estimated because outcome prediction is based on 1979-1981 data ***(Manganaro & Stark 2010)***.

Table (1): The APACHE II Severity of Disease Classification System

Physiologic Variable	High Abnormal Range				Low Abnormal Range					
	+4	+3	+2	+1	0	+1	+2	+3	+4	Points
Temperature - rectal (°C)	>41°	39 to 40.9°		38.5 to 38.9°	36 to 38.4°	34 to 35.9°	32 to 33.9°	30 to 31.9°	<29.9°	
MAP-(mm Hg)	>160	130 to 159	110 to 129		70 to 109		50 to 69		<49	
HR- (ventricular response)	>180	140 to 179	110 to 139		70 to 109		55 to 69	40 to 54	<39	
Respiratory Rate (RR) (non-ventilated or ventilated)	>50	35 to 49		25 to 34	12 to 24	10 to 11	6 to 9		<5	
Oxygenation: A-aDO_2 or PaO_2 (mm Hg) a. FIO_2 >0.5 record A-aDO2 b. FIO_2 <0.5 record PaO2	>500	350 to 499	200 to 349		<200 PO2>70	 PO2 61 to 70		 PO2 55 to 60	 PO2<55	
Arterial pH (preferred) Serum HCO3 (venous mEq/l) (not preferred, but may use if no ABGs)	>7.7 >52	7.6 to 7.69 41 to 51.9		7.5 to 7.59 32 to 40.9	7.33 to 7.49 22 to 31.9		7.25 to 7.32 18 to 21.9	7.15 to 7.24 15 to 17.9	<7.15 <15	
Serum Sodium (mEq/l)	>180	160 to 179	155 to 159	150 to 154	130 to 149		120 to 129	111 to 119	<110	
Serum Potassium (mEq/l)	>7	6 to 6.9		5.5 to 5.9	3.5 to 5.4	3 to 3.4	2.5 to 2.9		<2.5	
Serum Creatinine (mg/dl) Double point score for acute renal failure	>3.5	2 to 3.4	1.5 to 1.9		0.6 to 1.4		<0.6			
Hematocrit (%)	>60		50 to 59.9	46 to 49.9	30 to 45.9		20 to 29.9		<20	
WBC (total/mm3) (in 1000s)	>40		20 to 39.9	15 to 19.9	3 to 14.9		1 to 2.9		<1	
GCS = 15 minus actual GCS										
A. Total Acute Physiology Score (sum of 12 above points)										
B. Age points (years) <44=0; 45 to 54=2; 55 to 64=3; 65 to 74=5; >75=6										
C. Chronic Health Points (see below)										
Total APACHE II Score (add together the points from A+B+C)										

$A\text{-}aDO_2 = (FiO_2 \times 713) - PaCO_2 - PaO_2$

(Manganaro & Stark, 2010)

c- The APACHE III system

APACHE III (Table2) was introduced in 1991 with 17 variables for the APS component, reweighing of age and CHE components and expanding the number of disease groups to 78. Chronic Health and age points combined equal the physiological reserve points- an indicator of the patient's ability to recover from illness. The total score ranges between 0 and 299 ***(Vincent & Moreno, 2010).***

This version of APACHE consisted of a set of equations for predicting ICU and hospital mortality, ICU and hospital length of stay, risk of active treatment, duration of mechanical ventilation and the TISS score. Additional equations were constructed for use with patients undergoing CABG surgery. Periodically, these outcome predictions were re-evaluated and updated ***(Vincent & Moreno, 2010).***

Both APACHE II and III systems were shown to be useful with different degrees of success for evaluation of patient discrimination or calibration (the probability of death of patient population). They may be also useful for comparing performance of ICU's or trauma centers in different locations or the same establishments over-time ***(Keegan et al., 2008).***

The APACHE III score can be used alone only within homogeneous disease categories and then for severity stratification, not risk prediction. In addition, practitioners do not widely accept APACHE III, partly because it is proprietary and expensive. In addition, its accuracy needs to be convincingly validated in patients with trauma ***(Keegan et al., 2008).***

d- The APACHE IV system

APACHE IV, the last version of APACHE score system, published in 2006, to assess the severity of illness and prognosis in the ICU. APACHE IV was developed because the accuracy of APACHE III changed significantly over the last decade ***(Zimmerman et al., 2006).***

Table (2): APACHE III Points for Age and Chronic Health Evaluation

Parameter	Points
Age (years)	
≤44	0
45-59	5
60-64	11
65-69	13
70-74	16
75-84	17
≥85	24
Comorbid condition	
AIDS	23
Hepatic failure	16
Lymphoma	13
Metastatic cancer	11
Leukemia/multiple myeloma	10
Immuno-suppression	10
Cirrhosis	4

(Keegan et al., 2008)

There were several changes made in this new version of APACHE. The first excluded patients transferred from another ICU from receiving predictions. The second change involved measuring previous length of stay (LOS) as a continuous rather than an integer variable. The third change included a variable for designating whether a patient's GCS could not be assessed due to sedation. The most important change involved the new categorization of disease groups (there are 116 specific diagnostic category classifications) ***(Manganaro & Stark, 2010).***

When lead-time bias and disease are added to the APACHE III score (which used only to compare patients in the same disease category), a precise risk indicator is generated in the form of predictive equations) which allow comparisons across different disease categories ***(Zilberberg et al., 2009).***

The APACHE IV may provide objective data for resource allocation, can identify patients with anticipated favorable outcomes and can be used to provide benchmarks making it possible to estimate ICU lengths of stay, duration of mechanical ventilation and use of ICU therapy ***(Bakhshi et al., 2008)***.

Several factors are likely to account for the accuracy of APACHE IV mortality predictions. First, APACHE IV is based on the successful use of physiologic abnormalities for risk adjustment. Second, the accuracy of physiologic risk

adjustment was improved by adding rescaled PaO2/FIO2 and GCS variables and by reducing the impact of defaulting the GCS to a normal value when sedation or paralysis made direct assessment impossible. Third, case-mix adjustment was improved by increasing the precision of disease labeling. Finally, the continualadjustment for the prognostic impact of patient location before ICU admission and incorporation of new variables based on data availability and published information about their independent prognostic impact ***(Zimmerman et al., 2006).***

The APACHE IV model is subject to several limitations. First, although the large number of physiological variables account for the accuracy of APACHE IV predictions, it also contributes to its complexity. Second, it was developed and validated only in United State ICUs. International differences in bed availability, ICU structure, patient referral, selection criteria, and care before and after ICU are likely to have an adverse impact on predictive accuracy. Third, the results of the logistic regression analysis may have been influenced by the random assignment of patients to training or validation data sets. Also the small standard errors for the major variables and relatively narrow confidence intervals around the odds ratios suggest that uncertainty is not large ***(Zimmerman et al., 2006).***

II- Simplified acute physiology score

a- SAPS I

The SAPS I was first released in 1984 by **Le Gall et al** as an alternative to APACHE scoring. The model included age and 13 physiologic variables (HR, systolic blood pressure (SBP), temperature, RR/mechanical ventilation, urine output, BUN, hematocrit, WBC, glucose, potassium, sodium bicarbonate, and GCS score ***(Le Gall et al., 2006).***

SAPS scores these variables (0-4) in an identical manner to the APS of the APACHE system, adds a score for age (0-4) and replaces respiratory rate or the P(A-a) O2 which is difficult to measure with a fixed score of 3 for patients receiving mechanical ventilation or CPAP. The model was based on the most abnormal physiologic values in the first 24 hours after ICU admission but no input of pre-existing disease was included. It has been superseded by the SAPS II and SAPS III ***(Metnitz et al., 2007).***

Le Gall et al concluded that SAPS performed at least as well if not better than APS of the APACHE system but was more useful as it was much simpler. They stressed that SAPS is applicable to a wide range of pathologies but that its predictive value and performance can only be applied to groups of patients, not to individual patients ***(Moemen, 2004).***