REUE | Original Article

Risk scores for multiple organ failure in patients with multiple traumas treated in a hospital Emergency Department: a retrospective observational study

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BACKGROUND. Multiple organ failure (MOF) is the main cause of late death in patients hospitalized with multiple traumas in intensive care units. To prevent MOF, it is crucial to identify at-risk patients.

OBJECTIVE. To ascertain which of 4 risk scores (the Denver PostInjury MOF score [Denver MOF], the Sepsis-related Organ Failure Assessment [SOFA] score, the Marshall Multiple Organ Dysfunction [MOD] score, and the Denver Emergency Department Trauma Organ Failure [Denver ED TOF] score) would best predict mortality in polytrauma patients in our hospital emergency department.

METHODS. We studied 181 polytrauma patients over the age of 15 years who were brought to the emergency department in 2012 through 2018. The outcome of interest was 100-day mortality in patients who survived 48 hours. After excluding patients who died within 48 hours we calculated the risk scores for in-hospital MOD or MOF.

RESULTS. In the 181-patient series, 71.8% were men. The mean age was 49.8 years, and the mean injury severity score was 25.9. The predicted incidences of MOF by the 4 scores were as follows: 39.2% by the SOFA, 53% by the Denver ED TOF, 29.3% by the Marshall MOD, and 5% by the Denver MOF. The SOFA score emerged as probably the best predictor of 100-day mortality, with an area under the receiver operating characteristic curve of 0.773. The Denver ED TOF score had the best sensitivity, while the Denver MOF score had the best specificity.

CONCLUSIONS. The SOFA score gave the best balance between sensitivity and specificity. The Denver ED TOF score could be used for early risk screening, given that it can be calculated in less than 48 hours. Notwithstanding the results of our study suggest that, MOF and MOD still require more standardized definitions given the high incidence of morbidity and mortality in polytrauma patients.

Key words: Multiple organ failure. Multiple trauma. Sepsis-related Organ Failure Assessment (SOFA). Denver scores. Multiple Organ Dysfunction Score (MODS). Marshall score.

Uso de escalas predictoras de fallo multiorgánico en pacientes politraumáticos atendidos en urgencias hospitalarias: estudio observacional retrospectivo

INTRODUCTION. El fallo multiorgánico (MOD) es la principal causa de muerte tardía en pacientes politraumáticos hospitalizados en unidades de cuidados intensivos. La necesidad de identificar precozmente qué pacientes presentarán dicha complicación es importante a la hora de intentar prevenir su aparición.

OBJETIVO. Identificar qué escala predictora de mortalidad (Denver PostInjury MOF Score, SOFA score, Marshall MODs y Denver ED TOF) se ajustaba mejor a la evaluación pronóstica de los pacientes politraumáticos atendidos en nuestro centro.

MÉTODO. Se incluyeron 181 pacientes politraumáticos graves, mayores de 15 años, que llegaron al servicio de urgencias del hospital entre los años 2012-2018. Se estudió la mortalidad los primeros 100 días en aquellos que sobrevivieron 48 horas. Se excluyeron los fallecidos en las primeras 48 horas y se calcularon las escalas de mortalidad para determinar la aparición de disfunción multiorgánica (MODs) durante la hospitalización.

RESULTADOS. De los 181 pacientes incluidos, un 71,8% de ellos fueron hombres, la media de edad de 49,8 años y un índice de severidad (ISS) de 25,9. La aparición de MODs definida por SOFA predijo una incidencia del 39,2%, Denver ED TOF del 53% y Marshall MODs del 29,3%, mientras que Denver PostInjury MOF Score definió una incidencia del 5%. SOFA se postuló como la mejor escala para predecir la mortalidad (AUC 0,773). Denver ED TOF fue la escala con mayor sensibilidad, mientras que Denver PostInjury MOF Score obtuvo la mejor especificidad.

CONCLUSIONES. SOFA score presentó la mejor relación entre sensibilidad y especificidad. Denver ED TOF podría ser usada como *screening* ya que para su cálculo necesita menos de 48 horas.

Palabras clave: Fallo multiorgánico. Pacientes politraumáticos. SOFA score. Denver Score. Marshall Score.

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Article Information: Received: 17-3-2022. Accepted: 6-5-2022. *Online:* 13-5-2022.
Editor in Charge: Fernando Rosell Ortiz.

Introduction

Multiple organ dysfunction (MODs) continues to be the leading cause of late mortality in polytrauma patients admitted to intensive care units (ICUs), despite the reduction in early trauma-related mortality.[1] The incidence of post-traumatic multiorgan failure is approximately 29%, with mortality reaching 67% in patients with dysfunction of 2 organs, and up to 100% when dysfunction affects 4 organs.[2,4]

To date, no uniform definition of post-traumatic MOD exists,[3] which has led to the development of several scoring systems designed to evaluate respiratory, cardiovascular, hepatic, renal, neurological, and coagulation function. These mortality-predicting scales help estimate early—beyond the first 12 hours after trauma[5]—the expected severity for each patient.

According to current literature, three main validated scales exist for this purpose: the Denver Post-Injury MOF Score, the SOFA score, and the Marshall MODS[6] (Table 1).

Several studies have shown that the Denver score better identifies potentially severe patients since it is easy to calculate and accurately detects high-risk individuals.[2,7] In contrast, the SOFA score is the most frequently used in the literature and the most widespread today in ICUs.[8]

In 2014, Vogel *et al.*,[9] from the Denver Emergency Department, proposed a new scale aimed at predicting within the first 24 hours the risk of developing MOD during the initial 7 days. This new scale, named Denver ED TOF, includes clinically relevant and easy-to-obtain information (Table 1). Therefore, it may assist in the early recognition of patients at risk of developing MODs and help tailor therapeutic interventions.

At the request of the *Departament de Salut de Catalunya* (Catalonia, Spain), a working group was established in 2009, composed of experts from various specialties involved in the management of severe trauma patients. This group created an official registry designed by the Information Systems Directorate of CatSalut. The registry complies with the highest level of security required by the Spanish Data Protection Law (LOPD 15/1999), both in authorship and in access control. Each participating hospital has access to the global report and to the evaluation of its own data. *Hospital Universitari Joan XXIII* (HUJXXIII) (Tarragona, Spain) has been part of this commission since 2012.

The HUJXXIII has 332 beds and manages 244 emergency visits per day. It is the reference center for polytrauma patients in the province of Tarragona and is classified as CAT Level 2b according to U.S. trauma care criteria (Committee on Trauma of the American College of Surgeons[11]), serving a population of 800,000 inhabitants.

The aim of this study is to determine which MOD assessment scale (Denver, Denver ED TOF, Marshall, or SOFA) most accurately defines multiorgan failure in patients with severe trauma.

Methods

We conducted a retrospective observational study over a 6-year period (2012–2018). The study cohort consisted of polytrauma patients older than 15 years who required medical attention at the trauma reference hospital in the province of Tarragona (Spain).

From the CatSalut registry, the following data were collected: age, sex, mortality, prehospital information,

Table 1. Mortality scales and their items

Denver	**3**	**3**	**3**	**3**	
Respiratory: PaO_2/FiO_2	> 250	250-200	199-100	< 100	
Renal: Creatinine (mg/dL)	≤ 1.8	1.9-2.5	2.6-5	> 5	
Hepatic: Bilirubin (mg/dL)	≤ 2	2.1-4.0	4.1-8.0	> 8	
Cardiovascular	No inotropes and CI > 3 L/min/m^2	One low-dose inotrope or CI < 3 L/min/m^2	Any moderate-dose inotrope	Any high-dose inotrope	
SOFA	**0**	**1**	**2**	**3**	**4**
Respiratory: PaO_2/FiO_2 (mmHg)	> 400	< 400	< 300	< 200 with ventilatory support	< 100 with ventilatory support
Coagulation: Platelets × 10^3/_L	> 150	< 150	< 100	< 50	< 20
Liver: Bilirubin (mg/dL)	< 1.2	1.2-1.9	2-5.9	6-11.9	> 12
Cardiovascular: Hypotension (µg/kg/min)	No	MAP < 70	Dopamine < 5 or Dobutamine (any dose)	Dopamine > 5 or Epinephrine/ Norepinephrine < 0.1 µg/kg/min	Epinephrine/ Norepinephrine > 0.1 µg/kg/min
Glasgow Coma Scale	15	13-14	10-12	6-9	< 6:
Renal: Creatinine (mg/dL) or urine output	< 1.2	1.2-1.9	2-3.4	3.5-4.9 < 500 mL/day	> 5 < 200 mL/day
Marshall	**0**	**1**	**2**	**3**	**4**
Respiratory: PaO_2/FiO_2	> 300	226-300	151-225	76-150	< 75
Coagulation: Platelets × 10^3/µL	> 120	81-120	51-80	21-50	_< 20
Liver: Bilirubin (mg/dL)	< 1.17	1.18-3	3.1-7	7.1-14	> 14
Cardiovascular (PAR 1995)	< 10	10.1-15	15.1-20	20.1-30	> 30
Renal: Creatinine (mg/dL)	< 1.13	1.14-2.26	2.26-3.95	3.96-5.65	> 5.65
CNS: Glasgow Coma Scale	15	13-14	10-12	7-9	< 6
Denver ED TOF					
Prehospital or initial intubation	Age ≥ 65 years	Leukocytes ≥ 20,000/ µL	Hematocrit < 20% / 20–35%	SBP < 90 mmHg during initial care	Urea ≥ 30 mg/dL
3	**1**	**1**	**2/1**	**1**	**1**

mechanism of injury, response time, laboratory results, Glasgow Coma Scale (GCS), fluid therapy and transfusion requirements, need for mechanical ventilation, and surgical interventions. When data were missing from the registry, other hospital information sources were reviewed (radiology reports, nursing notes, clinical charts, etc.). Mortality within the first 100 days post-trauma was analyzed. The minimum sample size was estimated at 98 patients.

Polytrauma patients who died within the first 48 hours post-accident were excluded to avoid diagnostic confusion between multiorgan failure and complications related to inadequate resuscitation. Patients whose mechanism of injury involved burns, electrocution, or strangulation were also excluded because their pathophysiology differs substantially from the studied group, as well as those with incomplete data. Both general polytrauma patients and those with isolated traumatic brain injury (TBI) without other injuries were included. All patients were treated in the same ICU. Data required to compute the different scoring systems were collected from the second day of hospitalization until ICU discharge or death. The occurrence of multiorgan failure during ICU stay was recorded, and the worst-severity day was selected for analysis. Data from the preceding day were used if any variable was missing. Multiple organ dysfunction was defined as a SOFA score > 5, Marshall > 5, Denver > 3, or Denver Post-Injury (2014 version) > 3 for > 1 more days. When central venous pressure (CVP) data were missing, a normal value was imputed. Informed consent was obtained for inclusion of patient data in the CatSalut registry, and the study was approved by the CEIC of IISPV, which includes Universidad Rovira i Virgili (URV) (Catalonia, Spain).

Statistical analysis was performed using SPSS Statistics Version 22.0. For descriptive analysis of the different MODS groups, Student's t-test was used for continuous variables and chi-square for categorical variables with two groups; ANOVA was used for > 2 groups. Kaplan–Meier survival curves were used to compare 100-day post-accident mortality between patients who developed MODs and those who did not. Sensitivity analysis was performed using ROC curves to assess the association between mortality and MODs as defined by the different scoring systems.

Results

Study population

Of the 266 patients included in the study, a total of 85 were excluded, most for not meeting the age criterion (80 patients). A total of 181 patients met the inclusion criteria. Men predominated (71.8%), with a mean age of 49.8 years. Priority 0 transports and predominant mechanisms of injury are shown in Table 2. The Revised Trauma Score (RTS) had a mean of 11.23 (SD, 1.2), the ISS a mean of 25.9 (SD, 19.5), and the new Injury Severity Score (nISS) a mean of 29.29 (SD, 29.7). Significant injuries with an Abbreviated Injury Score (AIS) ≥ 2 were predominantly TBI (49.7%), pelvis (39.2%), and abdomen (27.6%). The mean length of stay was 21.28 days (SD, 25.98).

Table 2. Population Characteristics

	Patients N = 181 n (%)
Age (years) [mean (SD)]	49.8 (19.56)
Female sex	28.2
Revised Trauma Score [mean (SD)]*	11.23 (1.2)
Type of accident:	
Traffic accident	70 (38.6)
Falls / precipitated	54 (29.8)
Railway/metro/tram accident	1 (0.4)
Assault with a bladed weapon	6 (3.3)
Pedestrian struck	17 (9.3)
Drowning	2 (1.1)
Other	30 (16.6)
Type of transport	
Emergency Medical Services	179 (99.2)
Private means	2 (0.8)
Priority*	
0	87 (48.1)
1	90 (49.7)
Intra-/extra-hospital intubation	68 (37.6)
Substance abuse:	
Alcohol	43 (23.87)
Cocaine	5 (2.8)
Benzodiazepines	4 (2.2)
Cannabis	4 (2.2)
Amphetamines	1 (0.7)

*Priority level 0: hemodynamically unstable patients.
Priority level 1: patients with life-threatening injuries.

Among the patients treated in the resuscitation bay, 90 (49.7%) presented some degree of TBI. The 100-day mortality among the patients treated was 21.5% (39 patients), of whom 25 (69.4%) had sustained a TBI. The mean values of the various vital signs assessed at first hospital contact (Table 3) were stratified according to mortality. Regarding neurological status, the group of patients with TBI showed a significantly lower GCS score ($P < .01$, 95% CI, 2.318–6.223).

MODs by groups

Of the 181 patients studied, 76 (42%) did not develop MOD according to any of the four scales evaluated.

The incidence of MOD was SOFA: 39.2% (71 patients); Denver: 5% (9 patients); Denver Emergency Department Trauma (Denver ED TOF): 53% (96 patients); and Marshall: 29.3% (53 patients) Excluding the results obtained using the Denver scale, the other 3 scales (Denver ED TOF, SOFA, and Marshall) simultaneously diagnosed MODs in 49 patients (27.1%).

Comparison of demographic characteristics between patients who developed MODS and those who did not, according to each scale, is shown in Table 4. MOD defined by all scales was associated with older age, except Denver, which showed no association. Only MOD defined by SOFA showed a significantly higher incidence in men. All definitions of MODs were associated with a high severity index (ISS) and the need for blood transfusions within the first 24 hours. However, none of the scales associated surgical intervention with increased occurrence of multiple rgan failure.

Table 3. Vital signs according to survival

	Deceased N = 49 Mean (SD)	Survivors N = 132 Mean (SD)	*P*-value (CI)
Respiratory rate (rpm)	19.08 (21.577)	18.30 (12.450)	.770 (–7.622- 5.660)
O_2 saturation (%)	2.936 (3.013)	98.61 (2.936)	.503 –.757-1.537)
Heart rate (bpm)	90.68 (29.223)	90.61 (90.68)	.987 (–8.968-8.825)
Systolic blood pressure (mmHg)	114.47 (29.017)	124.93 (124.93)	.057 (–.344-21.271)
Glasgow Coma Scale	6.69 (5.182)	10.96 (5.512)	< .01 (2.318-6.223)

Clinically and analytically: SOFA-defined MODs were associated with elevated lactate, urea, and base excess, and lower hematocrit, platelet count, and $PaFiO_2$. Marshall-defined MODs were associated with lactate, hematocrit, urea, platelets, and $PaFiO_2$. Denver ED TOF-defined MODs were associated only with hematocrit, urea, and platelets. Of note, all scales showed an association with lower GCS scores, except the Denver scale, which was associated only with $PaFiO_2$ and low systolic blood pressure.

The mean length of the ICU stay was similar across scales, except for Denver, for which the mean stay was 9 days. Regarding the most affected organ systems according to each scale, for SOFA and Marshall the neurological system was the most frequently affected, followed by coagulation and respiratory systems. In contrast, according to Denver, the respiratory system was the most affected. Cardiac failure was identified more frequently using the Marshall scale vs the other scales.

MODs and mortality

Overall mortality was 21.5% (39 patients) within the first 100 days, and the survival rate was significantly lower among patients with MODs identified by all scales. The Denver scale yielded the lowest survival rate, followed by Marshall and SOFA, respectively (Figure 1). MODs diagnosed using the Denver scale was associated with the highest risk of death: Denver: RR 12.5, 95% CI, 3.86–41.16, $P < .001$; SOFA: RR, 8.62, 95% CI, 3.81–19.6, $P < .001$; Denver ED TOF: RR, 8.06, 95% CI, 3.62–17.85, $P < .001$; and Marshall: RR, 6.8, 95% CI, 3.42–13.51, $P < .001$

In the ROC curve (AUROC) analysis, we observed that, except for the Denver scale, the other 3 scales showed similar values. However, the scale with the largest AUROC was SOFA, making it the best discriminator of MODs in our patient population. The Denver scale seems to be the most specific, but it is very insensitive. Among the other scales, Marshall was the most specific and had reasonable sensitivity (> 70%), Denver ED TOF was the most sensitive but less specific, and SOFA demonstrated both balanced sensitivity and specificity (Figure 2).

Discussion

The SOFA, Marshall, Denver, and Denver ED TOF scales were created to define the presence of MODS. They differ substantially in the variables they include. Marshall and SOFA incorporate central nervous system (CNS) function and coagulation parameters. This may contribute to a higher incidence of MODs diagnosis, especially in patients with TBI. This may influence the predictive capacity of these scales, since TBI itself is associated with increased mortality among trauma patients. On the other hand, the cardiovascular system as assessed by Denver or SOFA uses a secondary parameter—namely, the use of inotropes—whereas Marshall uses physiological variables. Thus, many patients who require vasopressors to maintain adequate cerebral perfusion would score higher on SOFA or Denver. Another factor to consider is that most of these scales require a minimum of 48 hours to define the appearance of MODs, whereas the Denver ED TOF scale does not (it requires only a minimum of 4 hours).[9] By including variables available in the first few hours, it facilitates earlier classification of these patients.

Several studies have tied to determine which scale best defines MODs and its associated mortality. Suaia *et al.*[10] conducted a study of polytrauma patients and found that 101 patients (26%) developed MODs according to Marshall, SOFA, and Denver. In that study, Denver demonstrated the greatest specificity, accurately identifying patients at very high risk. A more recent study by Hutchings *et al.*[11] analyzed 491 patients and showed that Denver had the highest specificity (81%), whereas SOFA had the greatest sensitivity (73%). However, no differences were found in the area under the ROC curve among SOFA, Denver, and Marshall.

Our study shows notable differences in sensitivity, negative predictive value (NPV), positive predictive value (PPV), and specificity among the scales. The incidence rate of MODs in our work was 27.1% for the three scales combined, similar to the studies by Suaia *et al.*[10] (26%) and Hutchings *et al.*[11] (20.6%). Individually, SOFA yielded an incidence rate of 39.2%, Denver 5%, Denver ED TOF 53%, and Marshall 29.3%. Suaia *et al.*[10] reported similar figures for SOFA (32.7%), but substantial differences for Denver (22.2%) and Marshall (49.7%). Hutchings *et al.*[11] found a MODs incidence of 20.6% with SOFA, 22.8% with Denver, and 40.5% with Marshall—values considerably different from ours.

The considerable differences in MODs incidence rate across the scales stem from the different organs evaluated. The main difference between SOFA and Marshall compared with Denver is the exclusion in Denver of CNS dysfunction and coagulopathy. Neurological dysfunction appeared in 92 patients, which contributed to the increased incidence of MODs in SOFA and Marshall, as this dysfunction may have resulted from the cranial trauma itself but may also have been influenced by other variables. Because of this, the ability of SOFA or Marshall to detect true MODs cases is reduced (SOFA PPV 44.2%, Marshall PPV 50.1%) compared with Denver (PPV

Table 4. Characteristics of the population across different scales

	Polytrauma N = 181 n (%)	SOFA MOD	SOFA No MOD	*P* Value	Marshall MOD	Marshall No MOD	*P* Value	Denver (2014) MOD	Denver (2014) No MOD	*P* Value	Denver MOD	Denver No MOD	*P* Value
Characteristics of the patients													
Sex (male)	130 (71.8%)	45 (63.4%)	85 (77.3%)	.043	34 (64.2%)	96 (75%)	.140	65 (67.7%)	65(76.5 %)	.191	5 (55.65%)	125 (72.7%)	.266
Age (years)	49.88	56.23 (51.63-60.82)	45.7 (42.26-49.30)	< .001	55.32 (49.80-60.84)	47.63 (44.30-50.95)	.016	56.09 (52.11-60.08)	42.86 (39.19-46.56)	< .001	60.67 (46-47-74.87)	49.31 (46.38-52.25)	.090
Index Severity Score	25.91	38.13 (33.18-43.08)	18.03 (15.41-20.64)	< .001	39.62 (33.25-45.99)	20.23 (17.68-22.79)	< .001	33.58 (29.37-37.79)	17.25 (14.28-20.21)	< .001	41.22 (24.59-57.86)	25.11 (22.22-28)	.016
Vital signs and analytical data													
Respiratory rate	18.31	20.15 (13.58-26.72)	17.06 (15.81-18.31)	.271	21.64 (13.04-30.23)	16.81 (15.70-17.83)	.104	19.48 (14.14-24.82)	17.14 (15.80-18.48)	.395	16.75 (8.53-24.61)	18.43 (15.55-21-29)	.750
O_2 saturation (%)	98.53	98.47 (97.64-99.29)	98.57 (98.03-99.11)	.827	99.04 (98.31-99.78)	98.34 (97.78-98.90)	.173	98.51 (87.83-99.18)	98.56 (97.95-99.17)	.905	98.63 (96.39-100.86)	98.53 (98.06-99)	.928
Heart rate	90.62	89.81 (82.78-96.84)	98.57 (87.27-94.90)	.732	88.77 (80.55-96.99)	91.30 (87.55-95.05)	.526	91.38 (85.76-97)	89.85 (85.65-94.06)	.666	94.75 72-117.50)	90.41 (86.87-93.95)	.596
Blood pressure	122.85	120.56 (113.56-127.57)	124.22 (119.85-128.60)	.353	116.80 (108.44-125.15)	125.12 (121.22-129.35)	.043	119.42 (113.27-125.56)	126.59 (122.49-130.68)	.060	104.78 (85.71-127.84)	127.86 (120.04-127.67)	.025
Glasgow Coma Scale	10.01	5.04 (4.03-6.06)	13.27 (12.51-14.03)	< .001	4.13 (3.24-5.03)	12.58 (11.56-13.39)	< .001	6.41 (5.35-7.48)	14.04 (13.39-14.69)	< .001	7.44 (3.09-11.79)	10.15 (9.27-11.02)	.168
Base excess (mEq/L)	–4.10	-4.05 (-5.64- -2.45)	–2.68 (–2.56–-1.05)	.005	–5.15 (–7.35—2.95)	–3.52 (–4.75-–2.29	.162	–4.62 (–6.20-–3.06)	–3.20 (–4.56-1.84)	.217	–4.64 (–13.24-3.96)	–4.06 (–5.14-–2.98)	.798
Lactate	3.17	3.39 (2.47-4.30)	1.64 (1.29-2)	< .001	4.48 (3.18-5.77)	2.46 (1.98-2.94)	.001	3.41 (2.52-4.29)	2.75 (2.34-3.16)	.266	4.52(2.56-6.52)	3.08 (2.48-3.67)	.219
Bilirubin	0.65	0.75 (0.61-0.88)	0.58 (0.51-0.65)	.019	0.68 (0.56-0.81)	0.63 (0.55-0.72)	.536	0.69 (0.60-0.78)	0.60 (0.50-0.71)	.232	0.54 (0.40-0.68)	0.65 (0.58-0.73)	.468
Creatinine	2.61	3.34 (1.04-7.7)	1.6 (0.3-3.17)	.398	5.19 (1.06-11.04)	1.49 (0.15-2.82)	.108	3.55 (0.11-7.22)	1.49(0.06-2.91)	.333	8.49 (–6-22.95)	2.29 (0.19-4.38)	.197
Hematocrit	32.38	29.8 (27.31-32.29)	34.13 (32.75-35.52)	.001	29.73 (26.51-32.96)	33.59 (32.25-34.79)	.009	30.21 (28.29-32.13)	34.95 (33.29-36.62)	< .001	26.74 (20.18-51.18)	32.68 (30.49-38.96)	.500
Urea	37.14	40.92 (35.94-45.92)	34.56 (31.67-37.46)	.020	41.26 (34.88-47.64)	35.36 (32.70-38.01)	.045	41.97 (37.85-46.10)	31.41 (28.62-34.19)	< .001	35.65 (20.18-51.13)	37.22 (34.49-39.96)	.798
Leukocytes	13.25	13.49 (11.48-15.50)	13.09 (11.48-14.78)	.756	12.78 (10.79-14.62)	013.49 (11.90-15.08)	.568	13.42 (11.81-15.04)	13.05 (11.08-15.02)	.768	18.68 (10.08-27.27)	12.96 (11.72-14.20)	.045
Platelets	175.55	133.62 (117.09-150.15)	204.18 (190.36-218)	< .001	127.11 (109.01-145.22)	196.60 (183.27-209.92)	< .001	155.85 (139.86-171.85)	198.95 (182.99-215.01)	< .001	162 (95.85-228.14)	176.29 (164.3-188.28)	.596
PaO_2/FiO_2 ratio	413.19	367.67 (249.94-440.40)	545.19 (433.77-656.60)	.012	324.10 (236.80-411.40)	522.64 (444.34-600.94)	.001	404.65 (332.77-476.52)	446.28 (308.8-583.75)	.595	129.52 (80.80-178.24)	445.61 (380.37-510.85)	.002

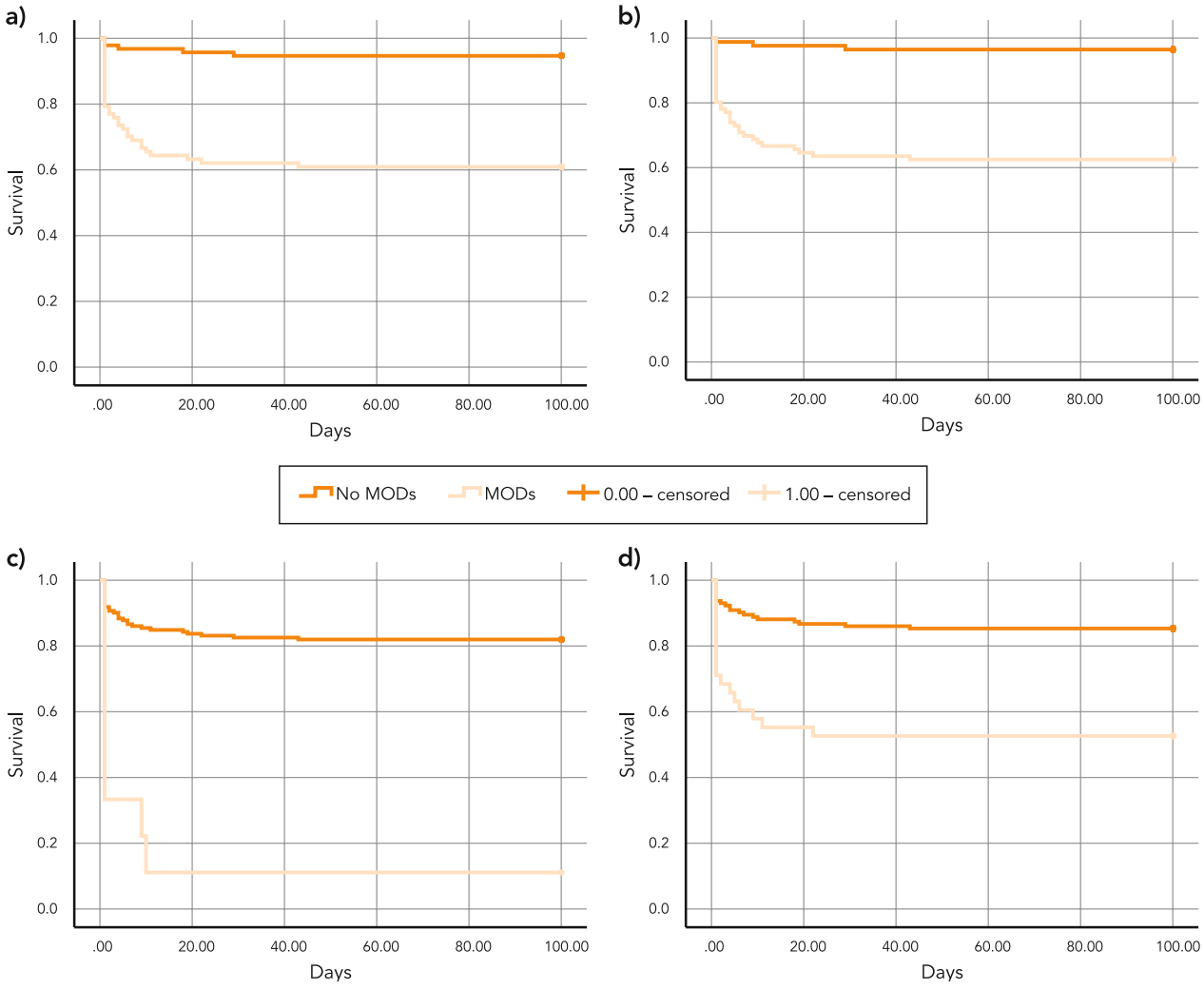


Figure 1. Kaplan–Meier survival curves: a) SOFA score; b) Denver ED TOF; c) Denver Post-Injury MOF Score; d) Marshall MODS.

88.61%). Other differences arise from the cut-off points each scale uses to determine hepatic, renal, and respiratory failure.

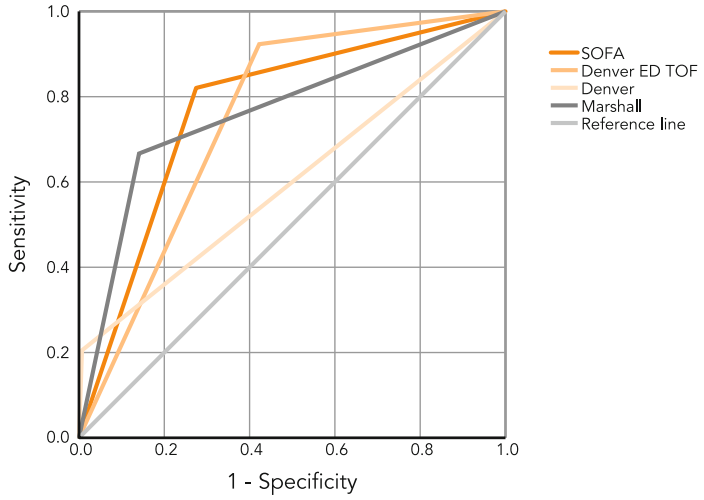
In our study, the appearance of multiple organ failure was strongly associated with increased mortality in these patients. The AUROC values were very similar across scales despite their differing validity parameters. The high specificity of Denver allows more aggressive therapeutic interventions to be applied safely to prevent MODs; however, due to its low sensitivity, many patients who might benefit would not receive these interventions because they would not be classified as at risk. A similar issue arises with the Marshall scale: although it has acceptable specificity, its sensitivity does not exceed 70%, meaning that 3 of every 10 patients would not be detected. At the other extreme, the Denver ED TOF scale, although reasonably sensitive, has a specificity below 60%, which could lead to overtreatment of patients who are not true candidates—thus increasing health care costs. Finally, the SOFA scale seems to classify trauma patients most appropriately, as it achieves the best AUROC despite not having the highest sensitivity nor specificity, positioning it as the most suitable scale. The Denver ED TOF scale demonstrated the highest RR of death among patients with MODs, although the AUROC differs considerably from that reported by Vogel *et al.*[9] in its original definition. In the validation study of this scale, the AUROC was 0.92, significantly higher than the 0.75 obtained in our study.

Several limitations exist in this study. One derives from the fact that our cohort was based on data from a single center. Many variables depended on electronic records, which were sometimes unavailable, although every effort was made to minimize missing data.

Another limitation is that the data analyzed began in 2012; protocols for managing polytrauma patients may have changed during the six-year study period, an aspect not examined in this work.

Conclusions

The Marshall, Denver ED TOF, and SOFA multiple organ failure assessment scales demonstrate similar capacity for predicting mortality in severely polytraumatized pa-



	Survivors with MODs	Survivors without MODs	Log rank	Sensitivity	Specificity	PPV	NPV	AUROC
SOFA	39 (54.95%)	103 (96.3%)	< 0.001	82.1%	72.5%	44.2%	93.8%	0.773
Marshall	26 (49.1%)	116 (90.6%)	< 0.001	69.2%	81.7%	50.1%	90.76%	0.755
Denver	1 (11.1%)	141 (82%)	< 0.001	20.5%	99.3%	88.61%	82.45%	0.599
Denver ED TOF	60 (62.5%)	82 (96.5%)	< 0.001	92.3%	57.7%	36.71%	96.57%	0.750

Figure 2. AUROC analysis of the different scales.

tients. The SOFA scale offers the most reasonable sensitivity-to-specificity relationship and therefore is recommended as the gold standard for defining post-traumatic MODs. For screening purposes, the Denver ED TOF scale appears to be the best option and could be recommended for use during the initial triage of patients.

ARTICLE INFORMATION

Conflict of Interest Disclosures: None reported.

Funding: The authors declare the non-existence of funding in relation to this article

Ethical Responsibilities: The authors have confirmed the maintenance of confidentiality and respect for the patient rights, agreement of publication, and transfer of rights to Revista Española de Urgencias y Emergencias.

This manuscript formed part of an undergraduate thesis at the Universidad Rovira i Virgili and was awarded first prize in its category at the "Premis Sant Lluc."

Article not commissioned by the Editorial Board and with external peer review.

Note of the editors: This is a BOWMAN-generated English translation of the officially indexed Spanish-language article, which should be cited as Rev Esp Urg Emerg. 2022;1:25-32. In this translated version, the editors have supervised the process; however, it cannot be ruled out that some errors resulting from the artificial intelligence translation process may have gone unnoticed.

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