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The use of extracorporeal membrane oxygenation in trauma patients

A national case–control study

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Abstract

Extracorporeal membrane oxygenation (ECMO) has been increasingly applied for the treatment of patients with trauma. Because a common complication of ECMO is bleeding, the use of ECMO support for patients with trauma was limited in the past. Studies have demonstrated a survival benefit from ECMO support in cases of traumatic lung injury, and it is likely that patients with other types of trauma would also benefit from ECMO support. However, the effect of ECMO in patients with other types of trauma is unknown.

Using the national insurance data of Taiwan, we identified 810 patients with trauma who received ECMO support from 2000 to 2010. Patients who died or who withdrew from the program within 7 days after discharge were defined as deceased. Logistic regression was used to estimate the odds ratio (OR) of death and 95% confidence intervals (CIs).

The overall mortality was 32.8% (266/810). A total of 417 patients received surgery during hospitalization, with an overall mortality of 39.0% (163/417). Patients who underwent thoracic surgery had an OR of 2.23 (95% CI: 1.49–3.34) compared with those who did not. Patients who underwent brain surgery had an OR of 2.86 (95% CI: 1.37–5.98) compared with patients who did not. Patients who received abdominal surgery had an OR of 4.47 (95% CI: 2.63–7.61) compared with patients who did not. All types of surgery had odds of mortality except orthopedic surgery; the use of ECMO with orthopedic surgery had an OR of 1.06 (95% CI: 0.69–1.62) compared with patients who did not receive orthopedic surgery.

Except for orthopedic surgery, patients with trauma who received ECMO support and required further surgery during hospitalization exhibited a relatively high mortality rate.

Abbreviations: CCI = Charlson Comorbidity Index, CI = confidence interval, ECMO = extracorporeal membrane oxygenation, ICD-9-CM = International Classification of Diseases, Ninth Revision, Clinical Modification, NOM = nonoperative management, OR = odds ratio, SD = standard deviation.

Keywords: extracorporeal membrane oxygenation, national health insurance research database, surgery, trauma

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1. Introduction

Trauma deaths exhibit a trimodal distribution pattern (immediate, early, and late death). Brain injury and bleeding are the leading causes of immediate and early death in patients with polytrauma.[1] Trauma care has somewhat improved in the past 30 years, but the prevalence of complications such as acute respiratory distress syndrome remains at approximately 13.4% to 18.1%.[2] Blunt chest trauma causes 25% of blunt traumatic fatalities. Only 10% of chest trauma cases require surgery,[3] and the primary management strategy for lung contusions is supportive care.[4]

Extracorporeal membrane oxygenation (ECMO) support can be used for patients with acute respiratory distress.[5] The most common complication from ECMO is bleeding.[6] In patients with trauma, multiple organs are frequently damaged and bleeding is a common cause of mortality.[1] Thus, the decision to use ECMO in patients with trauma can be problematic for clinical physicians. However, 1 cohort study indicated that patients with trauma receiving ECMO support might have a more favorable survival outcome than other critically ill patients.[7]

ECMO can be effective for treating hypoxic respiratory failure caused by traumatic lung injury combined with other injuries.[8] This may be attributable to the benefits of warming, correct acidosis, more favorable oxygenation, and circulation support.[9] Patients with trauma might require ECMO support for cardiac and pulmonary functions at various times. In any event, because the full scope of the effects of ECMO in patients with trauma are uncertain this study investigated the efficacy of ECMO in patients requiring surgery after trauma.

2. Materials and methods

2.1. Data source

This study used an inpatient database from the National Health Insurance Administration, Ministry of Health and Welfare, Taiwan, which includes insurant information and the inpatient claims of each insurant from 1996 to 2011. All residents of Taiwan must join the National Health Insurance program, so the database is comprehensive. Insurant identification numbers were recoded before the database was released to researchers to ensure patient privacy. This study was approved by the Research Ethics Committee of China Medical University and Hospital in Taiwan. The diseases and surgeries in the database were defined using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM).

2.2. Study population

In this case–control study, we enrolled 815 patients hospitalized because of trauma (ICD-9-CM codes 800–959) who received ECMO support (ICD-9-CM surgery codes 39.61 and 39.65) from 2000 to 2010 as the study population. Five patients with missing information concerning birth date or sex were excluded. Patients were categorized into 2 groups: death and survival. Patients who died or who withdrew from the National Health Insurance program within 7 days after discharge were included in the death group. All others were included in the survival group.

2.3. Risk factors

The risk factors were age, sex, Charlson Comorbidity Index (CCI) score, surgery during hospitalization, length of hospitalization, and medical center. The CCI comorbidities consisted of 19 diseases: myocardial infarction, congestive heart failure, peripheral vascular disease, cerebrovascular disease, dementia, chronic pulmonary disease, rheumatologic disease, peptic ulcer, mild and severe liver disease, diabetes with and without diabetic complications, hemiplegia, renal disease, malignancy without metastasis, leukemia, lymphoma, malignancy with metastasis, and acquired immunodeficiency syndrome.[10] Each CCI comorbid condition was weighted on the basis of its potential influence on mortality.[11] Surgeries included thoracic, abdominal, and brain surgeries.

2.4. Statistical analyses

Two-tailed P values $<.05$ were considered significant. Statistical analyses were performed using SAS software, version 9.4 (SAS Institute, Cary, NC). Categorical variables, namely age, sex, CCI score, year of ECMO use, type of surgery, and medical center were presented as numbers and percentages. The chi-squared test was used to assess the differences in categorical variables between the death and survival groups. Continuous variables, including age and length of hospital stay, were presented as mean and standard deviation. Student t test was used to assess the differences between continuous variables. Logistic regression was used to assess the risk of death and determine death-associated risk factors. Multivariable logistic regression was adjusted for age, sex, CCI score, year of ECMO use, surgery, length of hospital stay, and medical center. The joint effect of multiple surgeries on death was also estimated.

3. Results

A total of 62,162 patients received ECMO support in National Health Insurance inpatients database. A total of 810 patients with trauma receiving ECMO support were enrolled in this study, and 266 (32.8%) and 544 (67.2%) were included in the death and survival groups, respectively. Approximately 68% of the patients were younger than 60 years, and 75% were men (Table 1). No significant difference was evident with respect to age and sex between the death and survival groups. Compared with the survival group, the death group had a lower CCI score (71.8% vs 62.3% for a CCI score of 0) and length of hospital stay (15.0±22.2 vs 37.4±40.1 days). The use of ECMO increased during 2006 to 2010; however, the mortality rate was also increased (72.6% vs 57.9%). In the death group, a higher proportion of patients received thoracic (29.0% vs 18.2%) and abdominal surgeries (21.1% vs 9.01%), but a lower proportion of patients received orthopedic surgery (16.9% vs 26.8%).

Table 2 presents the association between death and death-associated risk factors revealed through logistic regression. The risk of death increased with age, but multivariable logistic regression revealed no significant differences related to sex. Patients receiving ECMO in the years 2006 to 2010 had a higher risk of death (odds ratio [OR]=1.92, 95% confidence interval [CI]: 1.34–2.76). Patients receiving thoracic (OR=2.13, 95% CI: 1.42–3.19), brain (OR=2.46 95% CI: 1.18–5.16), and abdominal surgeries (OR=4.19, 95% CI: 2.46–7.15) had higher risks of death than those who did not. The death group had a lower length of hospital stay than the survival group (OR=0.95, 95% CI: 0.94–0.96).

Table 3 presents the joint effect of surgeries on death for patients receiving thoracic, brain, and abdominal surgeries as revealed by multivariable logistic regression. Patients who underwent abdominal, brain, or thoracic surgery had a 6.07-, 4.37-, and 2.70-fold higher risk of death than those who did not undergo these surgeries. Patients who underwent 2 or more surgeries had a 3.60-fold increased risk of death.

4. Discussion

This study demonstrated that patients with trauma receiving ECMO support and requiring orthopedic surgery did not exhibit high mortality. Of the 810 patients enrolled in our study, 191 received orthopedic surgery during hospitalization. The mortality rate was nonsignificant between those who underwent orthopedic surgery and those who did not. However, patients who underwent other types of surgery did exhibit increased mortality.

Not every patient with trauma requires surgery; another study determined that the overall operation rate for patients admitted for trauma injuries was 54.6% at 2 academic level 1 trauma centers.[12] That study discovered that the most common surgery was orthopedic surgery (over 70%).[12] Long bone fracture is especially common in patients with polytrauma and can be managed through optimal external fixation.[13] Although primary nail fixation is the gold standard for isolated femur fractures, temporal external fixation achieves similar effects but with less blood loss and a shorter operating time in patients with

Table 1

Distribution of age, gender, and CCI score between death and survival patients.

	All N=810		Death N=266		Survival N=544		P-value
	N	%	n	%	n	%	
Age, y							.75
<40	323	39.9	112	42.1	211	38.8	
41–59	233	28.8	75	28.2	158	29.0	
60–69	112	13.8	37	13.9	75	13.8	
70+	142	17.5	42	15.8	100	18.4	
Mean (SD)	46.2		46.0		46.8		
Gender							.96
Women	205	25.3	67	25.2	138	25.4	
Men	605	74.7	199	74.8	406	74.6	
CCI score							.006
0	530	65.4	191	71.8	339	62.3	
1–2	216	26.7	52	19.6	164	30.2	
3+	64	7.9	23	8.65	41	7.54	
Means (SD)	0.67		0.63		0.69		.54
ECMO use year							<.0001
2000–2005	302	37.3	73	27.4	229	42.1	
2006–2010	508	62.7	193	72.6	315	57.9	
Operation							
Thoracic	176	21.7	77	29.0	99	18.2	.0005
Brain	46	5.7	22	8.3	24	4.4	.03
Abdominal	105	13.0	56	21.1	49	9.01	<.0001
Orthopedic	191	23.6	45	16.9	146	26.8	.002
Mean length of stay	30.0		15.0		37.4		<.0001
Medicine center	238	29.4	78	293	160	29.4	.98

Chi-square test and *t* test.
CCI=Charlson Comorbidity Index, ECMO=extracorporeal membrane oxygenation, SD=standard deviation.

Table 2

OR for death and associated risk factor.

Variable	Crude OR (95% CI)	P-value	Adjusted OR (95% CI)	P-value
Age, per 1 y increased	1.00 (0.99–1.01)	.61	1.01 (1.00–1.02)	.007
Gender				
Women	1.00		1.00	
Men	1.01 (0.72–1.42)	.96	1.04 (0.71–1.55)	.83
CCI score, per 1 score increased	0.96 (0.85–1.09)	.52	1.11 (0.96–1.29)	.17
ECMO use year (2006–2010 vs 2000–2005)	1.92 (1.40–2.64)	<.0001	1.92 (1.34–2.76)	.0004
Operation (yes vs no)				
Thoracic	1.86 (1.30–2.58)	.0005	2.13 (1.42–3.19)	.0003
Brain	1.95 (1.07–3.55)	.03	2.46 (1.18–5.16)	.02
Abdominal	2.69 (1.78–4.08)	<.0001	4.19 (2.46–7.15)	<.0001
Orthopedic	0.56 (0.38–0.81)	.002	1.06 (0.69–1.62)	.88
Length of stay, per 1 d increased	0.95 (0.94–0.96)	<.0001	0.95 (0.94–0.96)	<.0001
Medicine center (yes vs no)	1.00 (0.73–1.39)	.98	1.25 (0.86–1.82)	.24

Adjusted for age, gender, CCI score, ECMO use year, operation, length of stay, and medical center.
CCI=Charlson Comorbidity Index, CI=confidence interval, ECMO=extracorporeal membrane oxygenation, OR=odds ratio.

Table 3

Join effect of death risk among thoracic, brain, and abdominal operation.

Operation	N	Death no	Adjusted OR (95% CI)	P-value
None	393	103	1.00	
Only thoracic	111	51	2.70 (1.65–4.44)	<.0001
Only brain	20	11	4.37 (1.52–12.6)	.006
Only abdominal	56	33	6.07 (3.00–12.3)	<.0001
Only orthopedic	135	32	1.28 (0.77–2.13)	.33
Any two or more	95	36	3.60 (2.01–6.43)	<.0001

Adjusted for age, gender, CCI score, ECMO use year, length of stay, and medical center.
CCI=Charlson Comorbidity Index, CI=confidence interval, ECMO=extracorporeal membrane oxygenation, OR=odds ratio.

polytrauma.[14] In our study, 417 of 810 patients required surgery (51.5%), but only 191 patients required orthopedic surgery (23.6%). We discovered that undergoing orthopedic surgery did not increase mortality in patients receiving ECMO, and thus conclude that it is a beneficial alternative treatment.

Blunt abdominal trauma can be treated with nonoperative management (NOM). Blunt splenic injury is often treated with NOM to preserve spleen function, but the benefit of NOM remains controversial in patients with severe trauma.[15] Surgery is the last resort if NOM fails or if the patient's condition is unstable. However, the mortality rate for patients with severe blunt liver injury remains high even with appropriate management.[16] When surgery is required for patients with blunt abdominal trauma, this typically means their condition is particularly severe. This phenomenon may be attributable to hemodynamic instability, persistent bleeding, coagulopathy, or other complications of the injury.

Blunt chest injury accounts for 25% of blunt traumatic fatalities. Only 10% of patients with chest trauma require surgery,[3] and the primary management strategy for lung contusion is supportive care.[4] The condition of patients who require surgery tends to be much worse than that of patients who do not require surgery; thus, bleeding related to ECMO is not the only contributing factor to the increased mortality of these patients with severe injury.

Using anticoagulant therapy to prevent thrombosis during ECMO support is recommended. However, this therapy is contraindicated for patients with intracranial hemorrhage. A case report evaluated the management of venovenous ECMO without systemic anticoagulation in a patient with severe lung and brain injuries.[17] Another case series reported that patients with traumatic brain injury who received ECMO support had a relatively high survival rate and a low rate of neurologic sequelae.[18] Even patients with intracranial hemorrhage who required craniotomy exhibited a more favorable outcome with the use of ECMO.[19] Our study is the first to compare outcomes of patients who received ECMO support and underwent various types of surgery.

The use of ECMO increased 1.68-fold (302 vs 508 patients) in the period of 2006 to 2010. More people survived trauma injuries because of ECMO support, but the survival rate has since dropped from 75.8% to 62%. Some patients with trauma are eligible for ECMO treatment, while others are unable to benefit from ECMO. Thus, we deemed that ECMO should be applied to these selected patients with trauma to increase efficiency.[20]

Patients who underwent more than 2 types of surgery had lower rates of mortality than those who underwent brain, abdominal, or chest surgery alone. ECMO was a bridge to help patients recover from severe cardiopulmonary injury. The value of surgery for a patient with trauma depended on the type of injury and its relationship to homeostasis, decompression fixation, or functional repair.[12] However, we did not know the time interval between the multiple operations, and assumed that ECMO helped patients survive the most critical stages, which thus engendered the opportunity to undergo another operation. Therefore, the mortality rate was lower than for patients receiving only 1 operation.

5. Limitations

This study had some limitations. Information concerning the indication for ECMO was unavailable. Our database did not indicate whether patients with trauma required pulmonary or cardiopulmonary support. The venous-to-venous or venous-to-artery ECMO mode also could not be confirmed in our database. However, most patients with trauma likely received ECMO support under the venous-to-venous mode because of its benefits and risks. The time point when patients were removed from ECMO support during hospitalization was also unknown. According to previous experience, the survival rate decreases with prolonged ECMO use.[7,21] In addition, the time point when surgery was performed during hospitalization was unknown. Surgery may have been performed after removal of ECMO support. Orthopedic surgery is typically a less urgent and life-threatening surgery for patients with trauma. Although more research is necessary, our study suggests that patients with trauma who received ECMO support and required additional surgery exhibited a much higher rate of mortality than those who received ECMO support without surgery.

6. Conclusion

Except for orthopedic surgery, patients with trauma receiving ECMO support and requiring further surgery during hospitalization exhibited an increased mortality rate.

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