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A DONOR HEART SCORING MODEL TO PREDICT TRANSPLANT OUTCOMES

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Selection of heart donors is the most important stage on which the success of heart transplantation depends. **Objective:** to create a donor heart scoring model based on a number of donor characteristics. **Materials and methods.** The study used data from 650 brain-dead donors who underwent organ explantations between January 1, 2012 and December 31, 2017. In binomial logistic regression, non-selection of heart donor was used as a dependent variable, while donor characteristics were used as factor features. In regression model, the odds ratio was determined for each donor factor, which was transformed into points. The sum of the points of each of the donor factors included in the model was taken as the score of the donor heart. The proposed model was validated on a sample of donors for the period from January 1, 2019 to December 31, 2019; n = 218. **Results.** The model includes donor characteristics, such as age, cause of death (traumatic brain injury (TBI)/stroke), history of hypertension and diabetes, cardiac arrest with subsequent recovery, own pathology and traumatic heart disease, as well as heart rate, systolic blood pressure, arterial lactate, and need for norepinephrine immediately before organ harvesting. Based on the average value of the sum of points, low-risk donors (LRD ≤17 points) and high-risk donors (HRD ≥18 points) were identified. In the validation pool of donors, the proportion of heart failure among LRD and HRD was 4.1% and 78.6%, respectively, $p < 0.0001$, Pearson's χ^2 – 130.9. **Conclusion.** The presented donor heart scoring model accurately reflects the probability of using a donor's heart for transplantation and creates conditions for optimal distribution of heart transplants, especially from high-risk donors.

Keywords: donor heart scoring model, donor heart risk factors.

INTRODUCTION

When deciding on the suitability of a donor heart for transplantation, the specialists need to consider a large number of both donor and recipient factors in order to achieve optimal outcomes. It is often difficult to subjectively determine the total risk of heart transplantation, especially when it involves expanded criteria donors. In the world, there is a practice of using statistical models that determine the relationship between initial factors and final outcome to make an objective decision. In such models, the donor heart score is usually measured by the sum of the scores determined for each factor. The most famous models of this kind are the European model [1] and the model created by American researchers using the UNOS database [2]. Improving the assessment of the state of the donor heart, as well as standardizing the risk factors, are extremely pressing issues for improving the efficiency of heart transplantation [3].

MATERIALS AND METHODS

We used data from 650 brain-dead donors who underwent organ explantations from January 1, 2012 to December 31, 2017. In 198 (30.5%) donor cases, it was decided not to use the donor heart for transplantation. At the initial stage, a general analysis of the reasons for non-selection of a donor heart was conducted, taking into account the age category of donors. A comparative analysis of indicators between donor groups who died from traumatic brain injury (TBI) and stroke was carried out. Binary logistic regression was used to estimate the cumulative risk of using a donor heart for transplantation, the end point of which was non-selection of the donor heart. Independent factors were donor characteristics – age, sex, cause of death, high blood pressure, diabetes, circulatory arrest, lifetime heart disease and acute traumatic cardiac injury. The following indicators were considered in two values – mean arterial pressure (MAP), heart rate (HR), hemoglobin, pH, lactate, Na, glucose, norepinephrine need, and creatinine. The odds ratio (OR) obtained in the regression model was assigned, as a score, to each donor factor included in the model. The donor heart score was obtained by summing the scores of the factors encountered in a particular donor. Based on the mean value of the sum of scores, low-risk donors (LRD ≤17 points) and high-risk donors (HRD ≥18 points) were identified. A pool of 218 donors from January 1 to December 31, 2019 was used to validate the model presented. Verification of the model revealed

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a significant difference in the proportion of donor heart non-selection, depending on the donor heart score.

Data was processed using the SPSS23.0 software for Windows.

DISCUSSION AND RESULTS

The clinical characteristics of 650 donors were studied from January 1, 2012 to December 31, 2017 (Fig. 1). Heart explantation was performed in 452 (69.5%) donors, the heart was not used for transplantation in 198 (30.5%) cases. The distribution of reasons for non-selection of a donor heart are given in Fig. 2. It is noteworthy that in the older group of donors, own disease and heart injuries, high blood pressure, diabetes come out on top as the reasons for non-selection of a donor heart for transplantation.

In a group of donors under 50, non-selection due to severe concomitant injuries, including those affecting the chest organs, predominate. The number of rejections associated with poor donor homeostasis was comparable in both age groups.

Among all donors whose hearts were not used for transplantation, the number of those who died from stroke was 2.3 times higher than those who died from traumatic brain injury. Donors with stroke are significantly older than donors with traumatic brain injury ($p < 0.0001$). At the same time, donors with traumatic brain injury have worse homeostasis indicators than donors with vascular lesions due to the higher frequency of traumatic and hemorrhagic shock symptoms and severe hemodynamic disorders in donors with brain injury (Table 1).

Multivariate regression model of donor heart evaluation

Table 2 presents the donor factors significantly influencing the decision to reject a donor heart. Factors that did not demonstrate statistically significant influence on the decision to reject a donor heart were excluded from the model – donor gender, MAP, HR, hemoglobin, pH, lactate, Na, blood glucose and creatinine, and norepinephrine requirements recorded during the initial examination of a potential heart donor. Two factors showed possible credibility, lactate 2 ($p = 0.060$) and norepinephrine requirement – 2 (0.061), and we considered it possible to include them in the regression model.

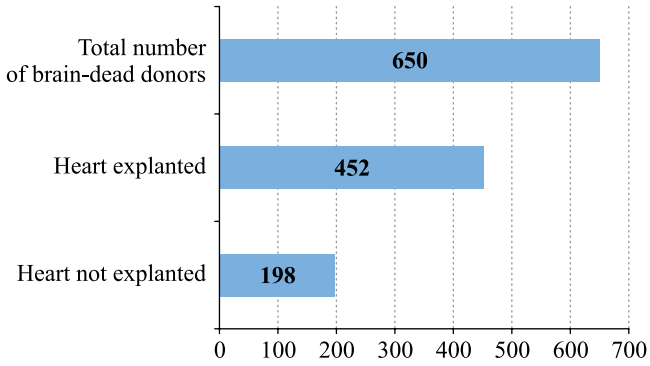

Fig. 1. Distribution of a pool of brain-dead donors included in the study

The degree of influence of each of the factors, determined by the OR value, was converted into scores. The ORs obtained from the regression model reflect the probability of donation depending on the presence/absence of a particular factor in the donor in comparison with the baseline values of donor factors. For example, the chance of refusing to use a heart for transplantation from a 56-year-old donor was 1.85 times greater than for a 46-year-old donor, whose OR value was taken as the baseline and was 1 point (Table 2). Table 3 shows how heart donor scores are calculated. A 46-year-old donor who died from cerebrovascular disease and had concomitant diseases with a score of 19 is considered a high-risk heart donor, while a 56-year-old donor,

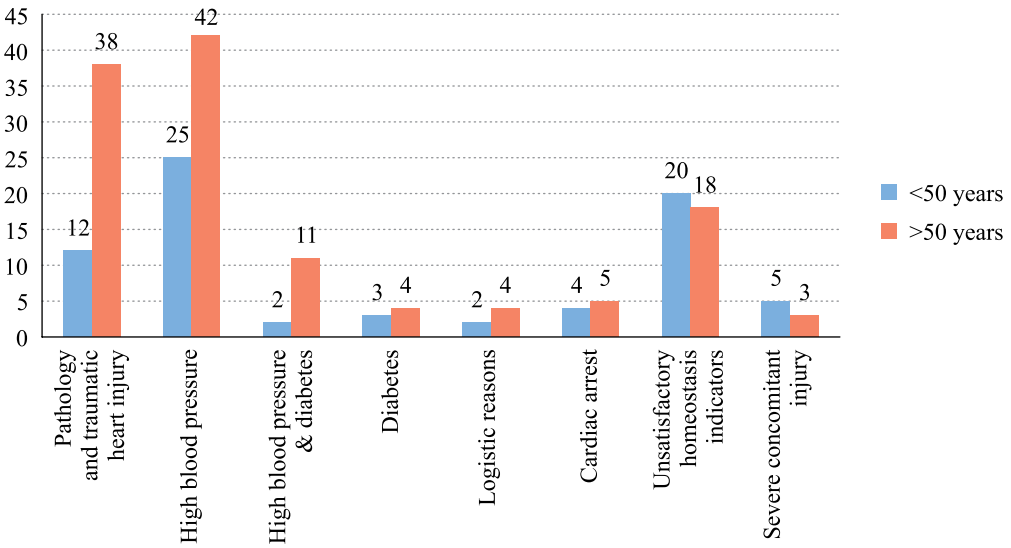

Fig. 2. Reasons for non-selection of donor heart

Table 1

Comparative analysis of donors whose hearts were not used for transplantation

Factor	TBI (n = 60)		Stroke (n = 138)		p
	Mean value	Min–Max	Mean value	Min–Max	
Age, years	46.4 (n = 60)	19–64	52.5 (n = 138)	27–67	<0.0001
pH, unit pH	7.38 (n = 49)	6.97–7.60	7.39 (n = 129)	6.90–7.62	0.47
Lactate, mmol/L	4.72 (n = 34)	0.7–22	2.74 (n = 94)	0.2–9.2	0.001
Na, mmol/L	149.7 (n = 49)	123–178	144.8 (n = 130)	131–183	0.007
Hb, g/L	102.9 (n = 48)	56–156	136.5 (n = 128)	48–186	<0.0001
Glucose, mmol/L	11.5 (n = 48)	6.0–31.0	10.3 (n = 127)	3.0–22.8	0.082
Creatinine, μmol/L	99.9 (n = 60)	47.0–239.0	103.0 (n = 136)	37.0–549.0	0.676
HA, ng/kg/min	560.4 (n = 60)	0.0–2000	442.9 (n = 134)	0.0–2500	0.125

Table 2

Regression model for evaluating donor heart. Dependent variable – non-selection of donor heart; 650 donors; January 1, 2012 to December 31, 2017

Factors	OR	Confidence interval	Points*	p
Age				
<45	0.35	0.237–0.504	1	
45–54	1.22	0.86–1.74	1	<0.0001
55–59	1.85	1.24–2.77	2	
>60	2.81	0.86–1.74	3	
Cause of death				
Stroke	1.51	1.06–2.16	2	0.024
TBI	0.66	0.46–0.95	1	
Hypertension				
Yes	1.96	1.39–2.8	2	0.001
No	0.506	0.36–0.72	1	
Diabetes				
Yes	1.97	1.19–3.26	2	0.009
No	0.51	0.31–0.843	1	
Circulatory arrest**				
Yes	23.99	3.05–188.72	24	<0.0001
No	0.042	0.005–0.33	1	
Pathology and traumatic heart injury***				
Yes	14.61	6.39–33.43	15	<0.0001
No	0.68	0.30–0.157	1	
Heart rate-2, beats/min				
<60	7.45	0.77–72.1	7	<0.0001
60–90	0.51	0.36–0.74	1	
>90	1.83	1.27–2.63	2	
SBP-2, mmHg				
<70	0.57	0.06–5.12	1	
70–110	0.63	0.44–0.91	1	<0.0001
110–150	1.42	0.97–2.10	1	
>150	3.03	1.11–8.25	3	
Lactate-2, mmol/L				
<2	0.58	0.37–0.89	1	0.060*
>2	1.72	1.13–2.64	2	
Norepinephrine-2, ng/kg/min				
<100	1.23	0.85–1.77	1	
100–600	0.785	0.56–1.10	1	0.061**
600–1000	0.813	0.45–1.46	1	
>1000	2.615	1.09–6.26	3	

Note. * Maximum 63 points, minimum 10 points. Low-risk donor ≤17 points, high risk donor ≥18 points. ** Circulatory arrest at pre-hospital or hospital stages. *** CHD, rhythm disturbances, pathology and valve replacement, traumatic heart injury.

without concomitant diseases, whose cause of death was traumatic head injury is regarded as a low-risk heart donor according to the proposed model. Rejection rate of donors who scored 19 and 13 points in the verification pool was 100% and 2.8% respectively.

The functionality of the proposed model was assessed using donor pool validation. The proportion (%) of rejections increased significantly, with total donor attainment of 18 points or more (Fig. 3). Rejections for LRDs and HRDs were 4.1% and 78.6% respectively. The difference is statistically significant ($p < 0.0001$), Pearson's chi-squared was 130.9.

CONCLUSION

We obtained an objective tool for primary assessment of a donor heart in the context of donor risk factors. The regression model reflects the evolution in the assessment of heart donors observed in Moscow over the past 10 years. Instead of a subjective assessment of each of the donor factors and their associated risks of poor transplant outcome, we have developed an evidence-based assessment system for donor heart refusal. The regression model can be used in the earliest stages of heart donor assessment as a tool for identifying high-risk donors. Undoubtedly, the final decision on the suitability of a donor heart for transplantation rests on specialists providing transplant care, based on, among other things, the results of invasive high-tech imaging studies, if necessary. However, at the initial stage of selection of a donor heart for transplantation, a simple and affordable tool that allows you to quickly present objective information about the donor to all interested transplant centers for preliminary selection of a recipient is needed.

Table 3

Example of how scores for heart donors are calculated

Factor	Donor 1	Points	Donor 2	Points
Age	46	1	56	2
Cause of death	Stroke	2	TBI	1
Hypertension	Yes	2	No	1
Diabetes	Yes	2	No	1
Circulatory arrest	No	1	No	1
Pathology and traumatic heart injury	No	1	No	1
Heart rate-2, beats/min	56	7	96	2
SBP-2, mmHg	103	1	89	1
Lactate-2, mmol/L	0.8	1	2.1	2
Norepinephrine-2, ng/kg/min	270	1	100	1
Total score		19		13

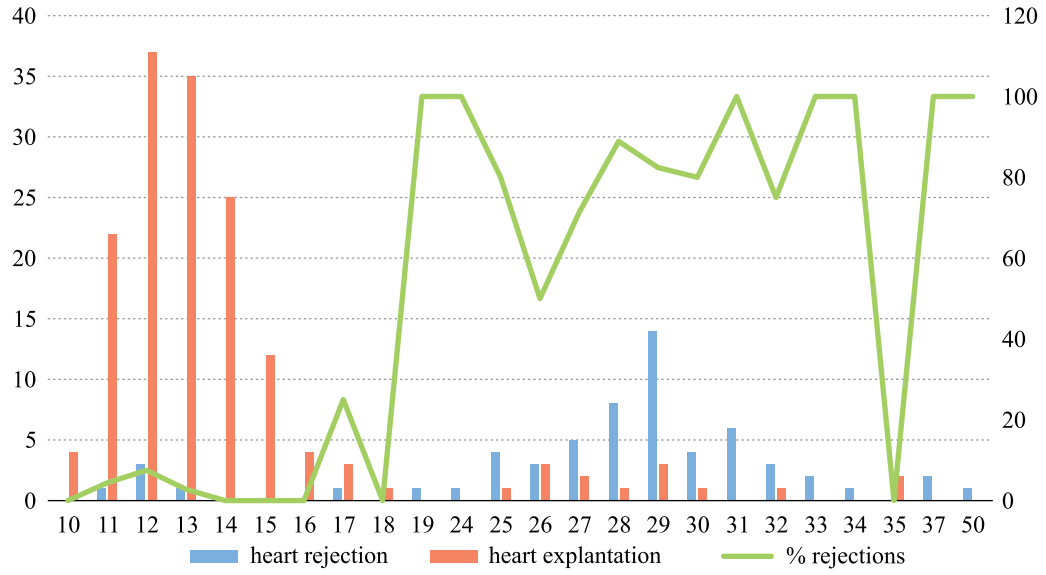

Fig. 3. Heart donor scores and proportion of rejection (%) in the validation pool of brain-dead donors

The authors declare no conflict of interest.

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