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Review / Derleme

A comparison of the results of the bicaval and biatrial surgical technique in orthotopic heart transplantation: A review and meta-analysis

Ortotopik kalp naklinde bikaval ve biatriyal cerahi teknik sonuçlarının karşılaştırılması: Derleme ve meta-analiz

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Background: This study aims to evaluate the outcomes of bicaval and biatrial techniques in orthotopic heart transplantation.

Methods: Between May 1966 and May 2011, a literature survey was conducted using electronic search engines including PubMed, Medline and Google and manually surveying the magazines on heart and vascular surgery. A total of 36 prospective and retrospective controlled studies which met the inclusion criteria were included in the meta-analysis. The outcomes of both techniques were evaluated using random and fixed-effect method, based on their significant heterogeneous nature. Statistical analysis was performed using Comprehensive Meta Analysis version 2 software.

Results: It was found that the results of eight meta-analyses obtained (tricuspid and mitral insufficiency, the need for permanent or temporary pacemaker, sinus rhythm, survival at 1 and 10 year, the right atrial pressure) were significantly improved in bicaval group, compared to the biatrial group.

Conclusion: Our study results showed that the outcomes of the bicaval technique were better, compared to biatrial technique. We believe that the bicaval anastomosis technique may have a positive effect on morbidity, due to its clinical and hemodynamical benefits.

Key words: Anastomosis; heart transplantation; meta analysis; review; surgical methods.

Amaç: Bu çalışmada ortotopik kalp naklinde bikaval ve biatriyal tekniklerin sonuçları değerlendirildi.

Çalışma planı: Mayıs 1966 ve Mayıs 2011 tarihleri arasında, PubMed, Medline ve Google gibi elektronik arama motorları ve kalp ve damar cerrahisiyle ilgili dergiler manuel olarak incelenerek, literatür taraması yapıldı. Kapsama kriterlerine uyan toplam 36 prospektif ve retrospektif kontrollü çalışma meta-analize dahil edildi. Her iki tekniğin sonuçları, anlamlı heterojenite olup olmamasına göre, rastgele ve sabit etki yöntemi kullanılarak değerlendirildi. İstatistik değerlendirme Comprehensive Meta Analysis version 2 yazılımı kullanılarak yapıldı.

Bulgular: Elde edilen sekiz meta-analiz sonucunun (triküspit ve mitral yetmezlik, kalıcı veya geçici pacemaker gereksinimi, sinüs ritmi, 1 ve 10 yıllık sağkalım, sağ atriyal basınç) anlamlı olarak bikaval grupta, biatriyal gruba göre daha iyi olduğu bulundu.

Sonuç: Çalışma bulguları, biatriyal tekniğe kıyasla, bikaval tekniğin sonuçlarının daha iyi olduğunu göstermektedir. Bikaval anastomoz tekniğinin sağladığı klinik ve hemodinamik yararlar göz önünde bulundurulduğunda, morbiditeyi olumlu yönde etkileyebileceğini düşünmekteyiz.

Anahtar sözcükler: Anastomoz; kalp nakli; meta-analiz; derleme; cerrahi yöntemler.

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Heart transplantation has become a widely used treatment choice that increases both the quality of life and expected life span of patients suffering from end-stage heart failure.[1,2] Although approximately 3500 heart transplantations have been performed, there are about 800.000 patients who have been identified as New York Heart Association (NYHA) class IV who urgently need a new organ.[3] In 1960, the biatrial orthotopic heart transplantation technique, as defined by Lower and Shumway,[4] was modified by Dr. Christian Barnard,[5] and it became the standard technique. In that technique, both atriums are anastomosed at the mid-atrial level. Additionally, the anatomic structure and geometric shape of the atriums change. Asynchronous atrial contractions can cause the regurgitation of atrioventricular heart valves,[6-8] and the need for a pacemaker could arise due to sinus node dysfunction (SND).[9] Therefore, the search for an alternative technique was started to overcome all of these issues. Bicaval transplantation, in which single left atrium anastomosis is performed, was first used in 1991 by Sievers et al.[10] on two patients. In 1993, Sarsam et al.[11] used the same technique on a broader patient population, and it became known as the "bicaval Wythenshawe technique". It has been reported that sinus node function is preserved in transplantations where the bicaval anastomosis technique is used, and as a result of the contribution of atrial contractions, stroke volume and heart performance have improved.[12]

Although heart transplantation has been performed all over the world for forty years, there still is no definitive choice for the atrial anastomosis technique. In this study, we aimed to examine the literature related to orthotopic heart transplantations and compare them by means of a systematic review and meta-analysis.

PATIENTS AND METHODS

Our systematic evaluation of the results of the bicaval and biatrial techniques used in orthotopic heart transplantations was based on the analysis of published data and research of both randomized and non-randomized controlled tests. A meta-analysis was used to compare two groups of patients who underwent heart transplantation using either the bicaval or biatrial techniques, and the following items were assessed: tricuspid and mitral valve insufficiency, temporary and the need for a permanent pacemaker, central venous pressure, right atrial pressure, pulmonary artery pressure, length of hospital stay, arrhythmia, pulmonary capillary wedge pressure, left atrial size, perioperative mortality, and the survival rates at one, three, five, and 10 years. After completing the comparison, the weighted mean difference (WMD) and its 95% confidence interval (CI) was then calculated.

Study inclusion and exclusion criteria

Retrospective and prospective controlled studies containing results regarding the bicaval and biatrial techniques of orthotopic heart transplantation were included in our review, which had no age, gender, or ethnic limitations. Case reports and series, letters, brief reports on experimental animals, uncontrolled studies, and review articles were not examined. The demographic characteristics of 36 studies included in the meta-analysis are provided in Table 1.[2,7,8,11,13-43]

Search strategy

A literature survey was completed by three independent authors according to caption, abstract, and full text as well as the inclusion and exclusion criteria mentioned above. The survey was conducted using electronic search engines such as PubMed, Medline, and Google and included information found up to May 2011. The terms "bicaval heart transplantation", "biatrial heart transplantation", "cardiac transplantation", and "heart transplantation" were used for the online research. The literature sources included in the study were searched manually, and the related articles provided by Pubmed were also reviewed. A total of 157 studies were retrieved. Ninety-three studies were excluded after reading the title and summary as they did not fit the inclusion criteria. Twenty-eight studies were excluded for reasons that are given in detail in Figure 1. In the end, 36 studies were included in the meta-analysis.

Data extraction

The information in each article included in the study was independently extracted by three authors. If the extracted raw data was approved by three authors according to the inclusion and exclusion critera, they were included in the study. The general characteristics of the published study (author, source country of the data, year of publication, study design, sample size, and number of incidents), demographic characteristics (gender, age), monitoring periods, results (tricuspid and mitral valve insufficiency, temporary and permanent pacemaker requirement, central venous pressure, right atrial pressure, pulmonary artery pressure, length of hospital stay, pulmonary capillary wedge pressure, cardiac index, left atrium size, arrhythmia, perioperative mortality, and the survival rates at 1, 3, 5, and 10 years), operation technique, and statistical methods were recorded.

Statistical analysis

A meta-analytical evaluation of the results of the bicaval and biatrial surgical techniques used in orthotopic heart transplantation as found in all of the

Table 1. Demographic characteristics of studies included in the meta-analysis

Study name	Year	Design	Country	Operative technique		Published journal
				Bicaval	Biatrial	
Park et al.[21]	2005	RS	South Korea	25	13	Asian Cardiovasc Thorac Ann
Aziz et al.[7]	1999	PNRCT	UK	96	105	J Thorac Cardivasc Surg
Solomon et al.[22]	2004	RS	New Zealand	37	38	Heart Lung Circ
Sarsam et al.[11]	1993	PRCT	UK	20	20	J Card Surg
el Gamel et al.[13]	1995	PRCT	UK	40	35	J Thorac Cardivasc Surg
Traversi et al.[23]	1998	NRCT	Italy	22	27	J Heart Lung Transplant
Kalra et al.[43]	2010	RS	USA	56	57	Echocardiography
Sievers et al.[10]	1994	PRCT	Germany	8	10	J Thorac Cardivasc Surg
Meyer et al.[17]	2005	RS	Canada	41	34	Can J Cardiol
Leyh et al.[14]	1995	PRCT	Germany	15	12	Ann Thorac Surg
Grant et al.[18]	1995	PS	UK	31	35	Br Heart J
Cui et al.[42]	2001	RS	USA	415	419	Am J Cardiol
Aleksic et al.[24]	1997	PRCT	Germany	17	14	Eur J Cardiothorac Surg
Grande et al.[42]	2008	RS	Italy	34	52	J Cardiovasc Med
Blanche et al.[26]	1997	RS	USA	101	56	J Cardiovasc Surg
Freimark et al.[39]	1995	RS	USA	13	15	Am Heart J
Brandt et al.[27]	1997	RS	Germany	30	30	Ann Thorac Surg
Weiss et al.[28]	2008	RS	USA	5207	6724	J Heart Lung Transplant
Grande et al.[25]	2000	PNRCT	Italy	46	71	Am J Cardiol
Laske et al.[29]	1996	RS	Switzerland	20	20	Eur J Cardiothorac Surg
Wang et al.[30]	2000	PRCT	Taiwan	20	39	Transplantation Proc
Milano et al.[31]	2000	RS	USA	75	68	Am Heart J
Rothman et al.[16]	1996	PS	USA	37	33	Circulation
Deleuze et al.[32]	1995	PS	France	41	40	J Thorac Cardiovasc Surg
el-Gamel et al.[41]	1996	PRCT	UK	24	13	J Heart Lung Transplant
Koch et al.[2]	2005	PRCT	Germany	139	158	Eur J Cardiothorac Surg
Riberi et al.[33]	2001	RS	France	106	72	Eur J Cardiothorac Surg
Cantillon et al.[19]	2010	RS	USA	7993	27994	Heart Rhythm
Beniaminovitz et al.[8]	1997	PRCT	USA	10	10	Am J Cardiol
Küçüker et al.[15]	2004	RS	Turkey	11	8	J Turkish Thorac Cardivasc Surg
Jung SH et al.[34]	2011	RS	Korea	148	53	J Korean Med Sci
Kendall et al.[35]	1993	PRCT	England	30	30	Transplant Proc
Pahl et al.[36]	2000	PS	USA	5	14	Pediatr Transplant
Sun JP et al.[38]	2007	RS	USA	322	293	J Heart Lung Transplant
Davies et al.[20]	2010	RS	USA	7661	11919	J Thorac Cardivasc Surg
Fiorelli et al.[37]	2011	PRCT	Brazil	15	15	Transplant Proc

RS: Retrospective study; PNRCT: Prospective non-randomized clinical trial; PRCT: Prospective randomized clinical trial; PS: Prospective study; UK: United Kingdom; USA: United States of America.

retrospective and prospective research was included in our study. Statistical analysis was done using the Comprehensive Meta-Analysis (CMA) version 2 software (Biostat, Englewood, New Jersey, USA). The odds ratio (OR) and its 95% CI were used for analyzing continuous variables while WMD and its 95% CI were used for analyzing dichotomous variables. A Cochrane Q test and I^2 statistics were used for the evaluation of heterogeneity between the results included in our study. A meta-analysis was performed by using either the fixed or random effect, depending on the availability of significant heterogeneity between the studies. In cases in which the heterogeneity was significant, ($p<0.1$, $I^2>50\%$) a random effect model was used, and if the heterogeneity was not significant ($p\geq0.1$, $I^2<50\%$), a fixed effect model was used. The whole effect was analyzed by using a Z score obtained by Fisher's Z transformation.

RESULTS

The meta-analysis results of all the significant studies are shown in Table 2-9.[2,7,8,10,11,13-18,20-29,31-35,37,38,40,41,44]

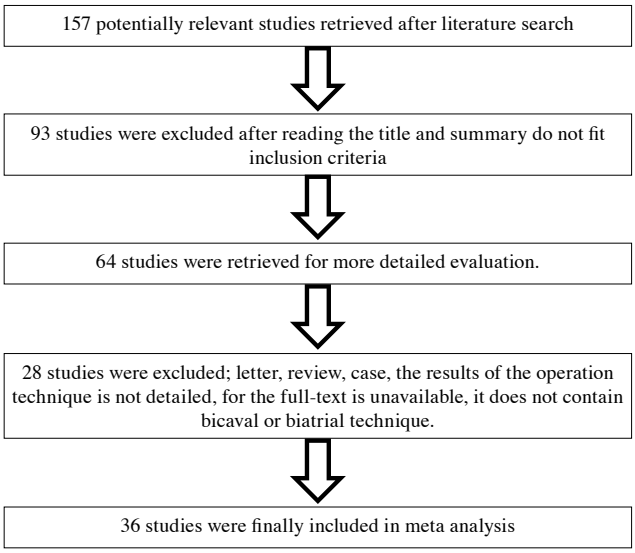

Figure 1. Flow chart of study identification.

With regard to tricuspid insufficiency, 14 of the study results have been implemented (Table 2, 3), and 10 (Table 7-9) of the study results for mitral valve insufficiency have been carried out. For atrioventricular valve insufficiencies, only those that were medium and advanced in nature were included in our evaluation. It was discovered that there was a significant decrease tricuspid and mitral valve insufficiency via the bicaval anastomosis technique (OR: 0.38, 95% CI: 0.236-0.602; OR: 0.48, 95% CI: 0.275-0.841, respectively).

The need for a permanent or temporary pacemaker commonly affects morbidity after orthotopic heart transplantations. A meta-analysis was undertaken with 10 studies involving a permanent pacemaker (Table 2, 3) and five studies involving a temporary pacemaker (Table 4-6). It was showed that the bicaval technique significantly decreased the need for these devices (OR: 0.37, 95% CI: 0.323-0.427; OR: 0.511, 95% CI: 0.323-0.809, respectively). Furthermore, the result of an analysis of four other studies revealed that the number of patients remaining in sinus rhythm with the bicaval technique was significantly high (OR: 0.22, 95% CI: 0.130-0.387).

An analysis of seven studies which looked at right atrial pressure values was carried (Table 7-9), and it was found to be significantly lower in the bicaval group (WMD: -1.54, 95% CI: -2.21 to -0.870). Eight studies involving the one-year (Table 4-6) and two studies focusing on 10-year survival rates (Table 7-9) were examined, and the values in the bicaval group were significantly higher (OR:0.82, 95% CI: 0.716-0.931; OR: 0.77, 95% CI: 0.729-0.817, respectively).

According to the results of the analysis of parameters included in meta-analysis, such as perioperative mortality (OR: 0.43, 95% CI: 0.068-2.766), three and five-year survival rates (OR: 0.76, 95% CI: 0.222-1.989; OR: 0.86, 95% CI: 0.209-3.538, respectively), central venous pressure (WMD: -0.57, 95% CI: -1.207 to -0.069), length of hospital stay (WMD: -.19, 95% CI: -0.506 to -0.125), pulmonary capillary wedge pressure (WMD: -0.19, 95% CI: -0.803-0.426), left atrium size (WMD: -1.91, 95% CI: -4.044-1.661), and arrhythmia (OR: 0.98, 95% CI: 0.098-9.784), no significant differences were found between the bicaval and biatrial groups.

DISCUSSION

Heart transplantation is an accepted treatment choice for end-stage heart failure today, and it has been proven to increase a patient's life span.[1,2] Although the bicaval surgical technique for orthotopic heart transplantation is commonly preferred, there is still no common consensus regarding the best technique to be used.

When transplantation is performed using the standard technique, the anatomic structure and geometric formation of the atriums are changed, and unsynchronized atrial contractions could cause the regurgitation of the tricuspid and mitral valve.[45] The bicaval anastomosis technique exclusively uses donor atriums, and resection of the recipient atrial tissue is done as much as possible.[11,13] According to this technique, the sinus node function is not impaired, and as a result of the contribution of atrial contractions, stroke volume and cardiac performance usually improves. Furthermore, atrioventricular valve function is preserved due to the protection of right atrial anatomy.[14]

Two separate meta-analyses were published in 2007 by Schnoor et al.,[46] which included uncontrolled tests, and in 2010 by Locali et al.,[47] which included only controlled studies. Schnoor et al.[46] inspected studies up to August 2006, and Locali et al.[47] took into account the studies up to January 2008. Our study added 35 more studies to the mix as we gathered information from articles up to May 2011. This not only increased the number of studies, but added new relevant information to the two previous meta-analyses.

Those who support the bicaval technique have reported that the impairment of atrial geometry coincides with the contractions of the two atrium pieces and that this could lead to tricuspid insufficiency in the early postoperative period. It has also been reported that mitral insufficiency could be related to the bending of the posterior leaflet, which is an extension of the left atrium endocardium that is dependent on the expansion of the anastomosed left atrium part.[15,48] The results

Table 2. Meta analysis for tricuspid regurgitation

Study name	Statistics for each study				Weight (random %)		
	Odds ratio	95% CI	Z value	*p* value	Relative weight	Bicaval n/N	Biatrial n/N
Park et al.[21]	0.209	0.049-0.889	-2.12	0.03	6.82	8/25	9/13
Aziz et al.[7]	0.197	0.082-0.473	-3.63	0.00	11.54	7/96	30/105
Solomon et al.[22]	1.328	0.327-5.389	0.39	0.69	7.11	5/37	4/38
Wang et al.[30]	0.239	0.076-0.751	-2.45	0.01	9.01	7/20	27/39
Beniaminovitz et al.[8]	0.167	0.015-1.879	-1.45	0.14	3.14	6/10	9/10
Sarsam et al.[11]	0.259	0.045-1.486	-1.51	0.13	5.26	2/20	6/20
el Gamel et al.[13]	0.861	0.199-3.733	-0.20	0.84	6.70	4/40	4/35
Traversi et al.[23]	0.170	0.041-0.712	-2.42	0.01	6.90	3/22	13/27
Sievers et al.[10]	0.333	0.044-2.523	-1.06	0.28	4.21	2/8	5/10
Meyer et al.[17]	1.264	0.500-3.194	0.49	0.62	11.03	18/41	13/34
Leyh et al.[14]	0.250	0.050-1.251	-1.68	0.09	5.90	5/15	8/12
Grande et al.[40]	0.293	0.014-6.288	-0.78	0.43	2.09	0/25	2/13
Sun et al.[38]	0.632	0.421-0.950	2.20	0.03	16.89	50/32	66/293
Kendall et al.[35]	0.042	0.004-0.418	2.70	0.00	3.41	1/13	10/15
Total random effect	0.377	0.236-0.602	4.08	0.00	100.0	118/703	206/703

Test for heterogeneity: Q-value= 23.63; df (Q)= 13; p value= 0.035; I^2= 44.98; Tau^2= 0.29.

Table 3. Meta analysis outcomes for permanent pacemaker

Study name	Statistics for each study				Weight (fixed %)		
	Odds ratio	95% CI	Z value	*p* value	Relative weight	Bicaval n/N	Biatrial n/N
Grant et al.[18]	0.147	0.007-2.971	-1.25	0.211	0.22	0/31	3/35
Meyer et al.[17]	0.089	0.011-0.742	-2.24	0.025	0.44	1/57	8/48
Aleksic et al.[24]	0.067	0.003-1.366	-1.75	0.079	0.22	0/17	4/14
Grande et al.[40]	0.125	0.007-2.340	-1.39	0.164	0.23	0/34	5/52
Blanche et al.[44]	0.016	0.001-0.273	-2.85	0.004	0.24	0/101	13/56
Brandt et al.[27]	1.000	0.131-7.605	0.00	1.000	0.48	2/30	2/30
Weiss et al.[28]	0.375	0.300-0.469	-8.60	0.000	39.51	103/5207	343/6724
Solomon et al.[22]	0.135	0.007-2.712	-1.30	0.191	0.22	0/37	3/38
Grande et al.[25]	0.130	0.007-2.409	-1.37	0.171	0.23	0/46	5/71
Davies et al.[20]	0.383	0.318-0.460	-13.8	0.000	58.22	146/7661	576/11919
Total fixed effect	0.371	0.323-0.427	-13.8	0.000	100.0	252/13181	386/18987

Test for heterogeneity: Q-value= 10.55; df (Q)= 9; p value= 0.30; I^2= 14.69; Tau^2= 0.01.

of Schnoor et al.[46] and Locali et al.[47] are similar to these findings. In addition, the Locali study showed no significant difference between the bicaval and biatrial groups in terms of mitral insufficiency. In our study, the frequency of tricuspid and mitral insufficiency was significantly lower in the bicaval group, which is similar to the findings in the Locali study. Jeevanandam et al.,[49] reported on a prospective study on the bicaval orthotopic heart transplantation technique, both with and without a prophylactic tricuspid annuloplasty in the vega. That study revealed that the mean pulmonary artery pressure and central venous pressure were lower while the right ventricular performance was higher. Furthermore, it indicated that in the first year, the number of patients suffering from ≥2+ tricuspid insufficiency was significantly lower in the group in which annuloplasty was applied, but there was no difference in renal functions.[49] The results of the meta-analysis for hemodynamic parameters in our study are given in detail in Table 10.[2,4,7,11,13,14,22,26,29,30-32,38,39]

Sinus node dysfunction is one of the reasons for morbidity after orthotopic heart transplantation,

Table 4. Meta analysis outcomes for temporary pacemaker

Study name	Statistics for each study				Weight (fixed %)		
	Odds ratio	95% CI	Z value	*p* value	Relative weight	Bicaval n/N	Biatrial n/N
Grant et al.[18]	0.635	0.232-1.739	-0.884	0.377	20.81	10/31	15/35
Laske et al.[29]	0.231	0.061-0.869	-2.167	0.030	12.01	6/20	13/20
el Gamel et al.[13]	0.402	0.154-1.049	-1.863	0.062	22.94	11/40	17/35
Wang et al.[30]	1.375	0.339-5.570	0.446	0.655	10.80	4/20	6/39
Grande et al.[25]	0.508	0.230-1.126	-1.668	0.095	33.44	13/46	31/71
Total fixed effect	0.511	0.323-0.809	-2.865	0.004	100.0	44/157	82/200

Test for heterogeneity: Q-value= 3.72; df (Q)= 4; p value= 0.45; I^2= 0.00; Tau^2= 0.00.

Table 5. Meta analysis outcomes for sinus rhythm

Study name	Statistics for each study				Weight (fixed %)		
	Odds ratio	95% CI	Z value	*p* value	Relative weight	Bicaval n/N	Biatrial n/N
Milano et al.[31]	0.36	0.181-0.731	-2.84	0.005	61.04	55/75	34/68
Rothman ety al.[16]	0.08	0.016-0.378	-3.16	0.002	11.88	35/37	19/33
Deleuze et al.[32]	0.14	0.045-0.427	-3.49	0.001	23.65	36/41	20/40
Laske et al.[29]	0.04	0.002-0.834	-2.08	0.037	3.44	20/20	13/20
Total fixed effect	0.22	0.130-0.387	-5.37	0.000	100.0	146/173	86/161

Test for heterogeneity: Q-value= 5.45; df (Q)= 3; p value= 0.14; I^2= 44.92; Tau^2= 0.34.

Table 6. Meta analysis outcomes for survival at one year

Study name	Statistics for each study				Weight (fixed %)		
	Odds ratio	95% CI	Z value	*p* value	Relative weight	Bicaval n/N	Biatrial n/N
Aziz et al.[7]	0.45	0.218-0.939	-2.13	0.033	2.07	13/96	27/105
Park et al.[21]	1.05	0.165-6.646	0.05	0.961	0.32	4/25	2/13
Weiss et al.[28]	0.84	0.751-0.936	-3.13	0.002	90.72	598/5207	901/6724
Kucuker et al.[15]	1.56	0.116-20.854	0.33	0.739	0.16	2/11	1/8
Koch et al.[2]	0.64	0.276-1.469	-1.06	0.290	1.58	10/72	19/94
Grande et al.[25]	0.60	0.111-3.231	-0.59	0.552	0.39	2/46	5/71
Jung et al.[34]	1.83	0.711-4.698	1.25	0.211	1.24	28/148	6/53
Sun et al.[38]	0.63	0.358-1.099	-1.63	0.103	3.51	23/322	32/293
Total fixed effect	0.82	0.742-0.916	-3.60	0.000	100.0	680/5927	993/7361

Test for heterogeneity: Q-value= 7.12; df (Q)= 7; p value= 0.416; I^2= 1.75; Tau^2= 0.002.

with a frequency rate of between 10%-43%.[50-52] It was also discovered that the permanent pacemaker application rate in SND was 3%-19%.[50-52] The biatrial technique might cause trauma in the sinus node or on its perinodal tissue and could impair its normal atrium morphology.[48,52,16] In the bicaval technique, almost the entire recipient right atrium can be excised, leaving an atrial cuff. The donor vena cava inferior and superior can be anastomosed to the recipient atrial cuff directly. Thus, the right atrium anatomy of the donor can be protected, and any possible sinus node damage can be prevented.[17] The Locali study[47] indicated that the frequency of postoperative arrhythmia decreased significantly in the bicaval group; however, the Schnoor study[46] revealed that the sinus rhythm was higher in the same group.

Meyer et al.[17] reported that although the cross-clamping and ischemia period was extended, the need

Table 7. Meta analysis outcomes for mitral regurgitation

Study name	Statistics for each study				Weight (random %)		
	Odds ratio	95% CI	Z value	*p* value	Relative weight	Bicaval n/N	Biatrial n/N
Beniaminovitz et al.[8]	0.64	0.101-4.097	-0.47	0.640	6.68	3/10	4/108
Traversi et al.[23]	0.11	0.013-0.990	-1.97	0.049	5.25	1/22	8/27
el Gamel et al.[41]	0.24	0.076-0.772	-2.40	0.017	12.06	5/40	13/35
Riberi et al.[33]	0.26	0.139-0.493	-4.15	0.000	19.05	35/106	47/72
Laske et al.[29]	0.16	0.017-1.500	-1.60	0.108	4.95	1/20	5/20
Solomon et al.[22]	3.16	0.125-80.193	0.70	0.485	2.67	1/37	0/38
Meyer et al.[17]	1.62	0.648-4.044	1.03	0.303	15.02	23/41	15/34
Deleuze et al.[32]	0.83	0.325-2.105	-0.40	0.690	14.77	27/41	28/40
Grant et al.[18]	0.29	0.014-6.288	-0.78	0.432	2.93	0/34	2/52
Sun et al.[38]	0.52	0.234-1.155	-1.60	0.108	16.64	10/322	17/293
Total random effect	0.48	0.275-0.841	-2.56	0.010	100.0	106/673	139/621

Test for heterogeneity: Q-value= 17.09; df (Q)= 9; p value= 0.05, I^2= 47.36; Tau^2= 0.32.

Table 8. Meta analysis outcomes for right atrial pressure

Study name	Statistics for each study				Weight (random %)		
	WMD	95% CI	Z value	*p* value	Relative weight	Bicaval M/SD	Biatrial M/SD
el Gamel et al.[41]	-2.75	-3.378 to -2.115	-8.52	0.000	14.11	3.6/1.3	8.8/2.4
Aziz et al.[7]	-1.46	-1.777 to -1.154	-9.21	0.000	15.58	4.4/4	10.9/4.8
Wang et al.[30]	-0.58	-1.126 to -0.028	-2.06	0.039	14.55	11/1	12/2
Sarsam et al.[11]	-2.13	-2.911 to -1.358	-5.38	0.000	13.26	4.9/2.1	9.6/2.3
Deleuze et al.[32]	-0.07	-0.464 to -0.314	-0.37	0.705	15.29	12.6/7	13/4
Blanche et al.[26]	-1.39	-1.031 to -7.557	-7.55	0.000	15.40	4/1	6/2
Fiorelli et al.[37]	-2.82	-3.836 to -1.813	-5.47	0.000	11.81	6.1/2.5	13.9/3
Total random effectt	-1.54	-2.210 to -0.870	-4.49	0.000	100.0		

WMD: Weighted mean diffference; Test for heterogeneity: Q-value= 79.13; df (Q)= 6; p value= 0.000; I^2= 92.41; Tau^2 = 0.73.

Table 9. Meta analysis outcomes for survival at 10 years

Study name	Statistics for each study				Weight (fixed %)		
	Odds ratio	95% CI	Z value	*p* value	Relative weight	Bicaval n/N	Biatrial n/N
Davies et al.[20]	0.776	0.732-0.822	-8.60	0.000	98.26	3264/7661	5828/11919
Sun et al.[38]	0.579	0.375-0.894	-2.46	0.014	1.74	41/322	59/293
Total fixed effect	0.772	0.729-0.817	-8.86	0.000	100.0	3305/7983	5887/12212

Test for heterogeneity: Q-value= 1.71; df (Q)= 1; p value= 0.190; I^2= 41.77; Tau^2= 0.018.

for a permanent pacemaker decreased statistically by a significant margin approximately 30 and 90 days after bicaval heart transplantations, when it was then found to be safe. Grant et al.[18] reported that the atrial geometry was better protected when the bicaval anastomosis technique was used, the incidence of postoperative atrial tachyarrhythmia was low, and the need for a pacemaker was decreased. When this occurred, patients were discharged earlier from the hospital. According to the United Network for Organ Sharing/ Organ Procurement Transplantation Network (UNOS/ OPTN) multivariable analysis results published by Cantillon et al.[19] in 2010, it was reported that the bicaval surgical technique was a powerful protector against the

Table 10. The results of the meta-analysis regarding hemodynamic parameters

	WMD	95% CI	*p*
Central venous pressure[22,29]	-0.57	-1.207 to 0.069	0.08
Pulmonary capillary wedge pressure[13,29,30]	-0.19	-0.803 to -0.426	0.55
Cardiac index[14,31,32,39]	0.50	0.272 to 0.733	0.00
Right atrial pressure[7,11,13,26,30,32,38]	-1.54	-2.210 to -0.870	0.00
Pulmonary artery pressure[2,4,7,26,38]	-0.38	-0.701 to -0.050	0.02

WMD: Weighted mean difference; CI: Confidence interval.

need for a postoperative pacemaker. In the same study, it was also shown that the biatrial surgical technique and increasing donor/recipient age were related to the necessity for a postoperative pacemaker. Our results related to the frequency of pacemaker application showed less occurrence in the bicaval group, similary to the findings in the aforementioned studies. Bouchart et al.[53] reported that patients who were subjected to biatrial transplantation with Doppler echocardiography had significant spontaneous echo contrast and left atrial thrombus. Furthermore, the early-to-late ventricular filling ratio (E:A) for the left ventricular filling pattern from cycle to cycle was higher. Nevertheless, that change reflects the presence of asynchronous contractions in the atrium recipient which could theoretically trigger contrast echo and thrombus formation inside blood flow stasis atrium related to asynchronous contractions.

The Schnoor study[46] stated that the one and three-year mortality rates decreased in the bicaval group but that there was no significant difference. The Locali study[47] gave no specific figures for mortality rates but reported that they also decreased in the same group. Our results indicated that when these two groups were compared, there was a significant difference between the preoperative and three-year survival rates, and the one and 10-year rates were significantly better in the bicaval group. In contrast, Wei et al.[54] found that both the short and long-term results were more satisfactory with the biatrial technique. In 2010, Davies et al.,[20] using the UNOS data, reviewed 20,999 patients who had undergone a heart transplant between 1997-2007. This data indicated that the surgical technique used from 1997 to 2007 changed significantly in favor of the bicaval method (0.2% in 1997 versus 97.6% in 2007; 62.0% versus 34.7%; p<0.0001). According to the same study, the COX regression analysis confirmed that the mortality rate in the bicaval group had significantly decreased over a 30-day period, and the long-term survival rate had decreased with the biatrial technique.

In conclusion, according to the results of our meta-analysis related to orthotopic heart transplantation, when parameters such as tricuspid insufficiency, mitral insufficiency, the need for a permanent or temporary pacemaker, right atrial pressure, one and 10-year survival rates, and sinus rhythm were compared, the bicaval anastomosis technique produced more satisfactory results than the biatrial anastomosis technique. Although the number of heart transplants varies by country and the number of clinics that can perform this procedure, there has been a considerable increase in the number of available donors and the number of patients who suffer from end-stage heart failure who need a new organ. Consequently, we think that a proper analysis of the results of surgical techniques, especially those dealing with the medium and long-term results, could affect mortality and morbidity considerably, even though survival rates will vary according to the experience of each clinic.

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