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Mitral and tricuspid annuloplasty ring dehiscence: a systematic review with pooled analysis

Arian Arjomandi Rad^a, Vinci Naruka^b, Robert Vardanyan^a, Alessandro Viviano^b,
Mohammad Yousuf Salmasi^c, Dimitris Magouliotis^d, Simon Kendall^e, Roberto Casula^b and
Thanos Athanasiou^{c,*}

^a Department of Medicine, Faculty of Medicine, Imperial College London, London, UK

^b Department of Cardiothoracic Surgery, Imperial College NHS Trust, Hammersmith Hospital, London, UK

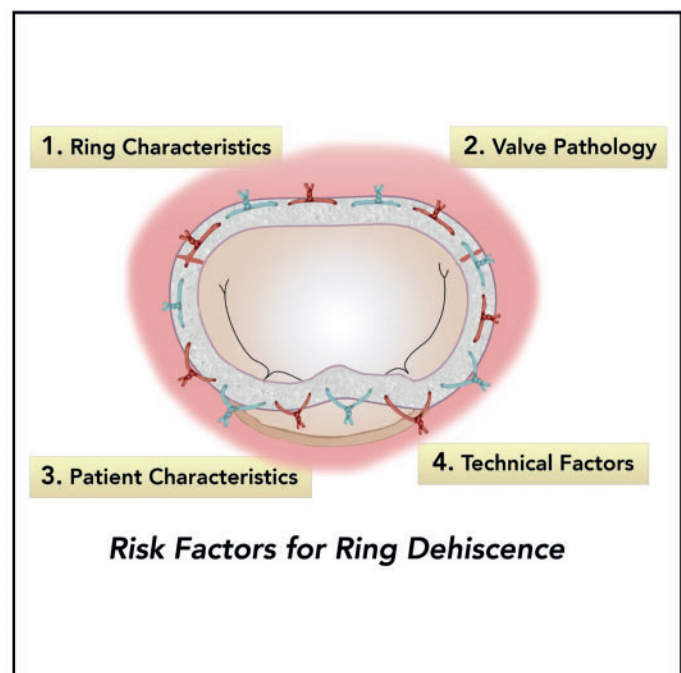
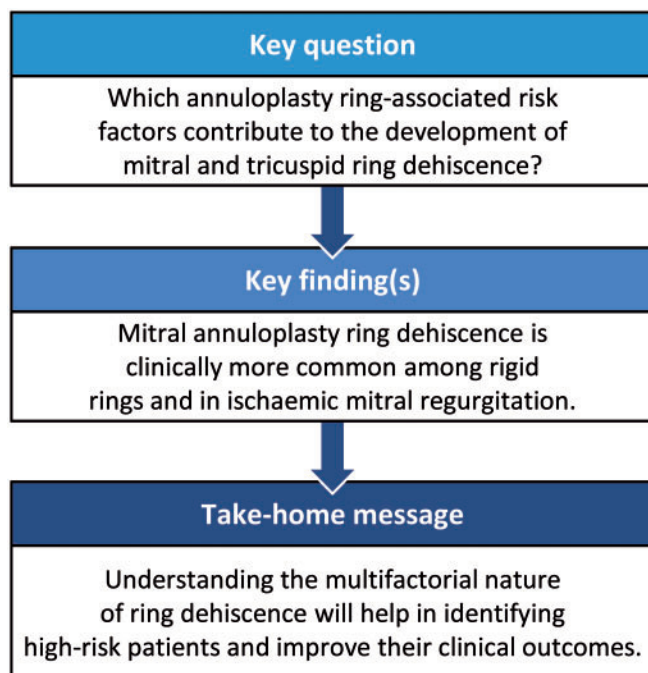
^c Department of Surgery and Cancer, Imperial College London, London, UK

^d Department of Surgery, Faculty of Medicine, School of Health Sciences, University of Thessaly, Larissa, Greece

^e Department of Cardiothoracic Surgery, James Cook University Hospital, Middlesbrough, UK

* Corresponding author. Department of Surgery and Cancer, 10th Floor QEOM Building, St. Mary's Campus, South Wharf Road, London W21NY, UK. Tel: +44 7990 505473; e-mail: t.athanasiou@imperial.ac.uk (T. Athanasiou).

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OBJECTIVES: Mitral and tricuspid ring annuloplasty dehiscence with consequent recurrent valve regurgitation is a rare but challenging procedural failure. The incidence and predisposing risk factors for annuloplasty ring dehiscence include technical and pathological ones.

METHODS: A systematic database search with pooled analysis was conducted of original articles that only included dehiscence rate of mitral and tricuspid ring in EMBASE, MEDLINE, Cochrane database and Google Scholar, from inception to November 2020. The outcomes included were dehiscence rate in mitral and tricuspid, type of ring implanted, dehiscence rate by pathology and by ring size and shape.

RESULTS: Our search yielded 821 relevant studies. Thirty-three studies met the inclusion criteria with a total of 10 340 patients (6543 mitral, 1414 tricuspid) of which 87 (mitral) and 30 (tricuspid) had dehiscence. Overall, dehiscence rate was 1.43%, diagnosed at a median of

4.5 ± 1.0 months postoperatively. A significant difference in mitral dehiscence rate was found by ring type (semi-rigid 1.86%, rigid 2.32%; flexible 0.43%; $P < 0.001$). There was no significant difference in rate of dehiscence by ring size ($P = 0.067$) and shape in mitral ($P = 0.281$) but there was higher dehiscence rate in ischaemic compared to non-ischaemic mitral regurgitation (3.91% vs 1.63%; $P = 0.022$). Among tricuspid studies, 9 of 10 studies did not report any dehiscence.

CONCLUSIONS: Although rigid, semi-rigid and flexible annuloplasty rings provide acceptable valve repair outcomes, mitral annuloplasty ring dehiscence is clinically more common among rigid rings. Understanding the multifactorial nature of ring dehiscence will help in identifying the patients at high risk and improve their clinical outcomes.

Keywords: • Dehiscence • Annuloplasty ring repair • Mitral regurgitation • Tricuspid regurgitation •

ABBREVIATION

3D Three-dimensional

INTRODUCTION

Ring annuloplasty successfully aims to restore leaflet coaptation, correct leaflet motion, repair annular shape and stability, reduce suture line stress and prevent subsequent dilation [1].

A rare but severe complication of surgical valve repair is ring dehiscence [2], defined as an acute or chronic event in which the sutures anchoring the annuloplasty ring pull-out from the annular tissue. This can be complete or partial and largely arises from inadequate suture implantation during surgery. Dehiscence eliminates the annular tension required for adequate leaflet coaptation and results in haemodynamic compromise, usually diagnosed using echocardiography. Whilst the true incidence of ring dehiscence in annuloplasty-based valve repair remains elusive and disputed, evidently, it is a pressing concern that contributes to a significant portion of surgical failures and subsequent reoperation [2, 3]. Particularly for annuloplasty-based mitral repair, 13–42% of postoperative procedural failures has been attributed to ring dehiscence, presenting an epidemiological disparity too great to ignore [3].

Certainly, numerous independent factors contributing to an elevated risk of ring dehiscence provide difficulty when analysing and comparing evidence. This multifactorial complication in surgical repair can be broadly divided based on 3 contributing categories: patient characteristics, surgeon experience and ring characteristics. Surgeons have a decision between using biologic or prosthetic rings, which can be further discriminated in terms of size, shape, completeness, and, in the case of prosthetic rings, rigidity resulting from the use of different core materials. Combined with the many associated patient and surgeon characteristics that can influence the risk of dehiscence, no substantive or systematic guidance yet exists in the indication and usage of different ring types.

However, the mitigation of dehiscence risk cannot be undervalued as the associated complications can be debilitating, complex and potentially lethal. Particularly, recurrence of regurgitation is a complication of ring dehiscence that postoperatively might portray surgery as a failure, with an incidence that is yet to be substantively described within literature [2]. Moreover, paravalvular leakage, haemolysis, endocarditis and device embolization are uncommon yet major complications that can arise due to dehiscence, with significant risks of developing subsequent heart failure, cardiogenic shock and patient mortality [2, 4, 5]. Therefore, prompt diagnosis of annuloplasty ring

dehiscence is crucial to averting the catastrophic complication that can arise. Echocardiography, fluoroscopy and an acute degree of clinical suspicion are essential tools in this regard.

This systematic review aims to analyse the evidence in the literature on the predisposing ring associated risk factors contributing to the development of mitral and tricuspid annuloplasty ring dehiscence.

METHODS

Literature search strategy

A systematic review was performed according to the Cochrane Collaboration published guidelines and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. A literature search of EMBASE, MEDLINE, Cochrane, PubMed and Google Scholar was conducted from database inception to November 2020 (Fig. 1). The full search strategy can be found in [Supplementary Material](#). Patient consent and IRB approval were not necessary in this study as no patients were deployed.

Study inclusion and exclusion criteria

We included all original articles reporting ring dehiscence after mitral or tricuspid valve repair with annuloplasty ring. Studies were excluded from the review if (i) the primary procedure performed in all patients was not repair with annuloplasty ring of the mitral or tricuspid valve; (ii) inconsistencies in the data precluded valid extraction; (iii) the study was performed in an animal model; (iv) ring dehiscence rate among patients was not reported; (v) the study population only included patients undergoing reoperation; (vi) the size of the study population was small (<30 patients). Case reports, reviews, abstracts from meetings and preclinical studies were excluded. By using the following criteria 2 reviewers (A.A.R. and R.V.) independently selected articles for further assessment after title and abstract review. Disagreements between the 2 reviewers were resolved by a 3rd independent reviewer (V.N.). Potentially eligible studies were then retrieved for full-text assessment.

Data extraction and critical appraisal of evidence

All full texts of retrieved articles were read and reviewed by 2 authors (A.A.R. and R.V.) and inclusion or exclusion of studies was decided unanimously. When there was disagreement, a 3rd reviewer (V.N.) made the final decision. Using a predetermined protocol data with regards to baseline, intraoperative and

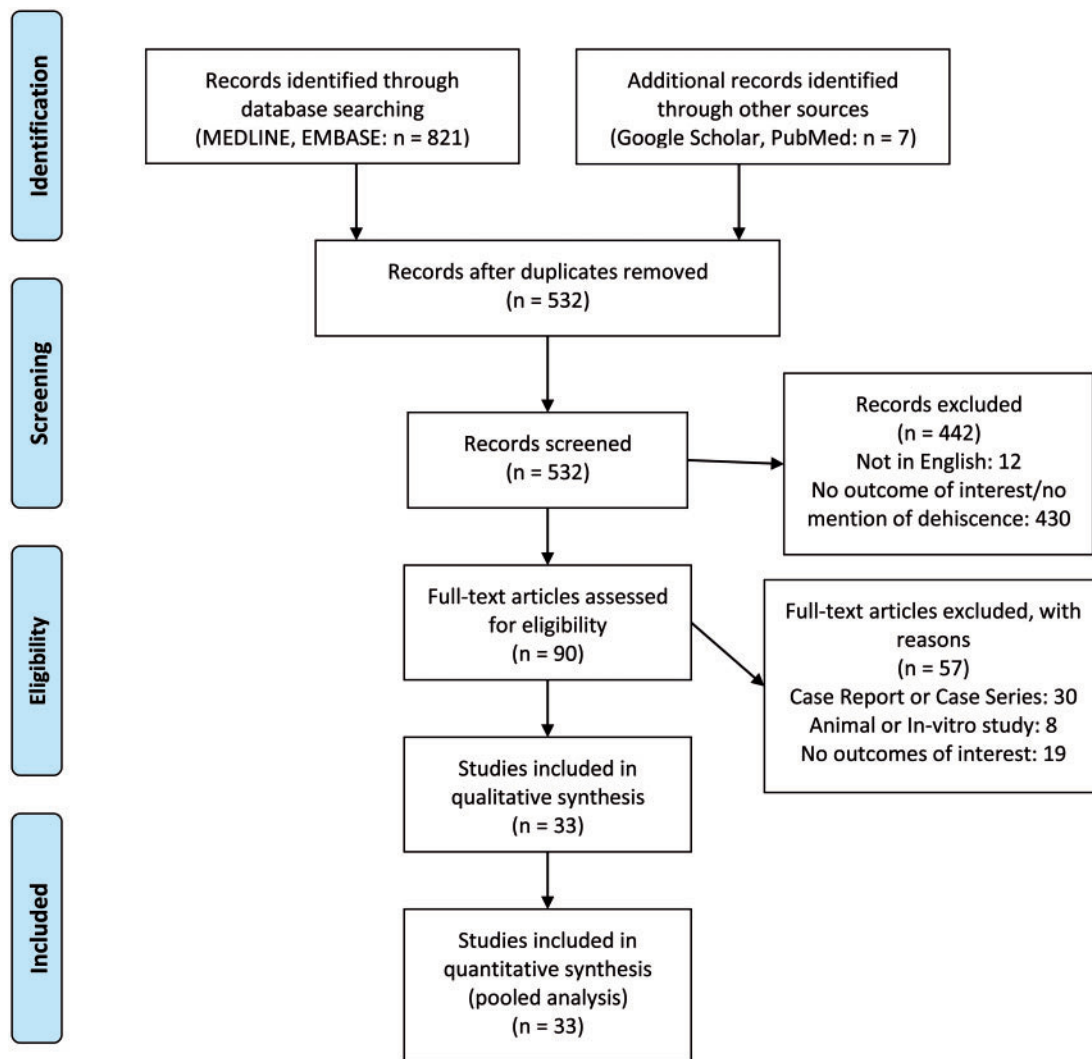


Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses tree.

postoperative parameters were collected. The following ring characteristics were collected: ring dehiscence rate in mitral and tricuspid, type of ring implanted (rigid, semi-rigid, flexible and biological), ring size, ring shape, valve regurgitation pathology (ischaemic and non-ischaemic) and 30-day mortality.

Data analysis

Unweighted statistical pooling of outcomes data was carried out using Fisher's exact or the chi-squared test and regarded a P -value <0.05 as significant (CI : 95%). We pooled results from each study including dehiscence rate for mitral annuloplasty ring repair by: ring type (flexible, rigid, semi-rigid and biological); ring shape and valve pathology (ischaemic vs non-ischaemic).

A meta-analysis of proportions was conducted assessing the event rate of dehiscence occurrence as the primary outcome measure, thus giving rise to effect-sizes per study included. Meta-regression analyses were performed to investigate the effects of covariates (age, Euroscore, NYHA, Diabetes, Ring size and pre-operative mitral regurgitation grade) on the dehiscence rate.

Statistical analyses were conducted using the Stata 13.0 software (Stata Corp., College Station, TX, USA).

Description of studies

Study characteristics are summarized in [Supplementary Material, Tables S1 and S2](#). The literature search identified 821 articles. Following critical appraisal, a total of 33 studies [6–38], incorporating 10 340 patients described outcomes for annuloplasty ring repair of the mitral or tricuspid valve and the reported rate of ring dehiscence were included and analysed. Twenty-three of the included studies (8131 patients) [6–28] focused on annuloplasty ring repair of the mitral valve while 10 studies including 2209 patients [29–38] focused on tricuspid. Baseline and intraoperative characteristics are summarized in [Supplementary Material, Tables S1–S3](#) and Table 1.

RESULTS

Incidence of dehiscence

To provide a more accurate representation of dehiscence prevalence among studies, the rate of dehiscence was calculated

Table 1: Annuloplasty and regurgitation overview in mitral population

Study	n of patients ^a	Ring type	Ring shape	Mean ring size mm (SD)	Ring range	Follow-up period (months)	Dehiscence rate (%)	Dehiscence (n)	Dehiscence rate (%)	Mean regurgitation grade preoperatively (SD)	Residual postoperative regurgitation grade >2+ (%)	Mitral Regurgitation Pathology (%)
Andreas et al.	94	Semi-rigid	Full	30 (2)	28–36	14	2.1	2	2.1	2.9 (0.9)	NA	Ischaemic (48); Degenerative (15); Dilatative (37)
Chen et al.	40	Semi-rigid	Full	26.3 (2.3)	24–30	32	2.5	1	2.5	3.6 (0.5)	4.8	Non-ischaemic (100)
Jyrala et al.	98	Flexible	Partial	NA	NA	57	1.02	1	1.02	3.8 (0.5)	NA	Non-ischaemic (100)
Lange et al.	405	Semi-rigid	Partial	30.7 (2.2)	26–36	25	1.73	7	1.73	NA	9.6	Non-ischaemic (80.5), ischaemic (19.5)
Langer et al.	35	Rigid	Full	32.0 (NA)	28–36	6	0	0	0	3.2 (0.6)	8.6	Non-ischaemic (100)
Lawrie et al.	469	Flexible	Full	28.9 (2.8)	NA	51	0	0	0	3.5 (0.2)	14.7	Non-ischaemic (88.7), ischaemic (4.7), endocarditis (3.5)
Nigro et al.	36	Flexible	Full	30.0 (NA)	26–34	12	2.56	1	2.56	3.7 (0.5)	7.7	Non-ischaemic (100)
Noack et al.	3478	Rigid (9%), semi-rigid (89%)	Full	NA	NA	67	rigid (0.32), semi-rigid (1.32)	Rigid (11), semi-rigid (46)	0.23	NA	NA	Non-ischaemic (100)
Guenzinger et al.	166	Rigid	Full	34.7 (3.5)	28–40	19	1.8	3	1.8	3.2 (0.3)	15.6	NA
Shin et al.	420	Rigid (67.5%), flexible (25.9%), semi-rigid (2.1%)	Full	NA	NA	29	0.23	1	0.23	3.9 (0.4)	9.4	Non-ischaemic (89), ischaemic (6), infective endocarditis (5)
Shimokawa et al.	730	Rigid (11.3%), semi-rigid (43.6%), biological (19.6%)	Full (44.9%), Partial (22.8%)	NA	NA	68	1.36	10	1.36	NA	NA	Non-ischaemic (87.6); endocarditis (12.4)
Miura et al.	107	Biological	Partial	28.7 (NA)	26–32	140	0	0	0	4 (NA)	10.6	Non-ischaemic (86); Infective endocarditis (14)
Guenzinger et al. (2)	63	Rigid	Full	29.7 (1.8)	26–32	19	4.76	3	4.76	3.0 (0.4)	20.7	Ischaemic (100)
Spencer et al.	95	Flexible	Full	NA	NA	NA	1.05	1	1.05	NA	10.5	Non-ischaemic (87.4), endocarditis (4.85), ischaemic (7.8)
Maisano et al.	30	Semi-rigid	Full	NA	NA	12	3.33	1	3.33	3.9 (0.5)	6.7	NA
Mori et al.	86	NA	NA	NA	NA	12	3.49	3	3.49	4 (NA)	NA	Non-ischaemic (94%), endocarditis (6%)
Ram et al.	654	NA	NA	33.1 (3.6)	25–40	67	0.77	5	0.77	NA	NA	Non-ischaemic (86.9), endocarditis (13.1)
Shimizu et al.	119	Semi-rigid (64.7%), rigid (2.5%), flexible (21.3%)	Full	29 (NA)	25–40	85	0.85	1	0.85	3.55 (0.8)	NA	Endocarditis (100)
Zegdi et al.	31	Rigid	Full	NA	NA	140	3.33	13	3.33	3.1 (0.8)	4.1	Non-ischaemic (100)
Bevilacqua et al.	74	Rigid (51% and semi-rigid (49%))	Full	32 (2)	NA	36	0	0	0	NA	NA	Non-ischaemic (100)
De Bonis et al.	56	Biological	Partial	33.2 (1.4)	NA	36	9.8	5	9.8	NA	11.1	Non-ischaemic (100)
	135	Rigid (84%), flexible (7.8%), biological (7.9%)	Full	34.6 (3.2)	NA	138	0.75	1	0.75	NA	12.1	Non-ischaemic (100)
Bogachev-Prokophiev et al.	86	Semi-rigid	Full	32 (NA)	NA	25	1.2	1	1.2	4 (0)	15.2	Non-ischaemic (100)
	86	Flexible	Full	34 (NA)	NA	25	0	0	0	4 (0)	9	Non-ischaemic (100)
Kron et al.	116	Rigid/semi-rigid	Full	27.8 (1.8)	NA	24	3.6	4	3.6	3.92 (0.4)	48.1	Ischaemic (100)

^aPatients are those that have been followed up and at risk of having dehiscence.

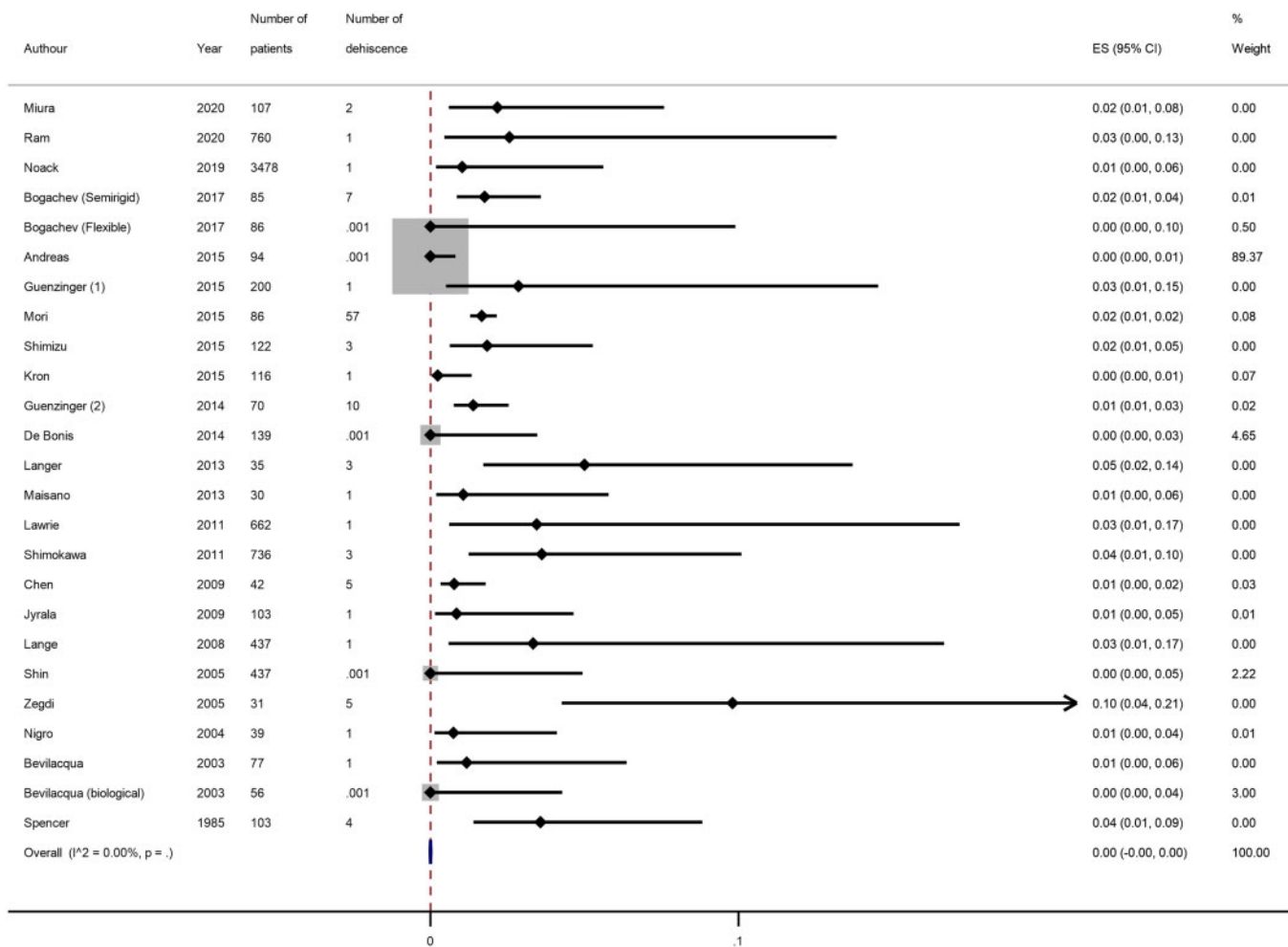


Figure 2: Meta-analysis of proportions, summarizing the effect estimates based on the incidence of valve dehiscence reported in each study.

among the patients who were at risk of developing the complication, thus excluding patients lost or dead upon echocardiographic follow-up (Fig. 2). Therefore, the overall studies population was of 9718 patients (7709 mitral; 2009 tricuspid) (Table 1, Supplementary Material, Table S3). In the overall cohort 139 (1.43%) patients presented with annuloplasty ring dehiscence of either mitral or tricuspid valve. Among mitral studies, the median follow-period was of 31 ± 8 months and dehiscence ranged from 0% to 9.8% (mean 1.85%). In the tricuspid population, the median follow-period was of 21 ± 3 months and only one study conducted by Pfannmüller *et al.* [33] reported dehiscence among patients at 4.8%, the remaining 9 studies reported no incidence among their patients.

In the mitral cohort, 12 studies [6, 8, 9, 12–14, 16, 18, 20, 22, 24, 28] with 5901 patients, of whom 95 had dehiscence, provided the time of dehiscence occurrence, which resulted in a median of 4.5 ± 1.0 months from the first operation.

Meta-regression analysis: influence of covariates on valve dehiscence rate

Meta-regression identified the prevalence of diabetes in the study populations to significantly influence the incidence of valve dehiscence (coefficient -0.03; 95% CI -0.05 to -0.01; $P = 0.007$), as well as a significant effect of preoperative MR grade (coefficient

Table 2: Meta-regression analysis: influence of covariates on valve dehiscence rate

	Coef.	Standard error	95% CI	P-value
Age	-0.0733	0.0367	-0.1508 to 0.00423	0.062
EuroSCORE	-0.178	0.0650	-0.457 to 0.102	0.112
NYHA	-0.0589	0.4726013	-1.0886 to 0.971	0.903
Diabetes	-0.0297	0.00846	-0.0489 to 0.0106	0.007
Ring size	0.184	0.0895	-0.0132 to 0.381	0.065
MR grade	-1.423	0.620	-2.774 to 0.0719	0.041

Bold values indicate the presence of a statistically significant difference with $P < 0.05$, 95% CI.

-1.43; 95% CI -2.77 to -0.07; $P = 0.041$). Interestingly, the effect of age and ring size trended towards a significant effect on dehiscence rate although this did not reach significance ($P = 0.062$ and 0.065, respectively). Euroscore and NYHA were not significantly related to dehiscence rate (Table 2).

Dehiscence rate by ring type

Four types of rings were analysed: rigid, semi-rigid, flexible and biological.

Table 3: Key results

	Ring characteristic	Dehiscence rate (%)	P-value (CI 95%)
Overall cohort	Mitral	1.43	-
	Tricuspid	0 in 9 studies, 4.8 in 1 study	
Mitral (ring type)	Flexible ring	0.04	<0.001
	Semi-rigid ring	1.55	
	Rigid ring	2.96	
	Biological ring	3.07	
Mitral (ring size)			0.067
Mitral (ring shape)	Full	1.40	0.281
	Partial	1.95	
Mitral (pathology)	Ischaemic	3.91	0.022
	Non-ischaemic	1.64	

Among the mitral studies, 6 used semi-rigid [6, 7, 9, 13, 20, 27], 5 used rigid [10, 13, 14, 18, 24], 5 used flexible [8, 11, 12, 19, 27] and 2 used biological rings [17, 25]. The incidence of dehiscence among ring types was the following: 0.04% flexible; 1.55% semi-rigid; 2.96% rigid and 3.07% in biological (number of patients, respectively: 784; 3750; 608; 163). A significant difference in dehiscence rate in the mitral population was found both between the 3 prosthetic ring types (semi-rigid versus rigid versus flexible; $P < 0.001$) and upon inclusion of the biological ring population (semi-rigid versus rigid versus flexible versus biological; $P < 0.001$). A significant difference in dehiscence rate was also found when separately comparing flexible to rigid rings ($P < 0.001$).

Among the studies in the tricuspid annuloplasty ring group, 5 used flexible [33, 34, 36–38] and 9 used rigid rings [29–31, 34–38] (number of patients, respectively: 649 and 1360). The incidence of dehiscence was reported as 0% in 9 of the studies, only 1 study reported 8.7% in rigid and 0.9% in flexible [33].

Dehiscence rate by ring size and shape

In the mitral cohort, a total of 15 [6–12, 14, 15, 17, 18, 22, 23, 25–28] studies comprising 2714 patients reported data on ring sizes used. Meta-regression coefficients were not significant for dehiscence rate and ring size (coefficient 0.184, 95% CI -0.013 to -0.381, $P = 0.065$).

A total of 16 studies with 5438 patients used full rings while 4 studies used partial ring with 666 patients. No significant difference in dehiscence rate was found between full and partial rings (1.4% full vs 1.95% partial; $P = 0.281$).

Among the tricuspid studies, analysis was not possible due to the nature of the data.

Dehiscence rate by pathology

Studies were classified based on the causative pathology of regurgitation into ischaemic and non-ischaemic. Non-ischaemic included degenerative, functional, rheumatic, infectious and congenital mitral regurgitation. In the mitral cohort, 2 studies included ischaemic patients [19, 28] while 12 studies included non-ischaemic patients [7, 8, 10, 12, 13, 18, 21–27]. The ischaemic group consisted of 179 patients reporting a dehiscence rate of 3.91% while the non-ischaemic group consisted of 4155

patients reporting a dehiscence rate of 1.64%, a significant difference between the 2 groups was found ($P = 0.022$).

DISCUSSION

Incidence of dehiscence and the impact of covariates

The results of our analysis (overall 1.43% dehiscence rate) are in line with the ones reported in the literature which range from 1% to 10% dehiscence incidence [13]. It is thanks to the rapid advances made during the last decades with regards to imaging technologies and the development of three-dimensional (3D) transoesophageal echocardiography that a more comprehensive visualization and understanding of the valve annulus motion during the cardiac cycle has been gained [39]. Kronzon *et al.* [40] also demonstrated the potential of 3D transoesophageal echocardiography in providing information regarding the shape, size and area of the dehisced valve segment. The advancement of these technologies allowed for further improved design of annuloplasty rings and consequent enhanced treatment of valve regurgitation. Although dehiscence could be considered a rare complication, it constitutes a significant cause of postoperative failure of mitral and tricuspid valve repair [41].

The present study has found, by means of meta-regression, that dehiscence can be influenced by clinical covariates, namely the presence of diabetes or the increased severity of preoperative MR, as well as potentially age. This may indicate that pre-existing valvular pathology, patient physiology and potentially quality of the tissues all have an influence on the risk of repair dehiscence. However, the low event rate in each of the studies limits the robustness of our analysis, and the association between patient covariates and dehiscence certainly requires further research.

Dehiscence rate by ring type

The results of our analysis showed marked differences in rate of dehiscence among different types of rings in the mitral annuloplasty ring repair group (Table 3).

Short- and long-term outcomes of mitral annuloplasty ring repair with flexible and rigid rings have been found to be often comparable in terms of long-term survival, mortality, reoperation and recurrence of regurgitation [42, 43]. Nevertheless, preclinical

and clinical studies postulated rigid annuloplasty rings to result in higher rates of dehiscence both for the mitral and tricuspid valve [13, 33, 44]. By being a dynamic structure, the valve annulus plays an active role in the function of the valve system, with the superficial sinospiral-bulbospiral muscles and deep sinospiral muscles contracting and relaxing. Flexible rings have been used to reduce the annular size, they are designed to allow for the physiological motion of the valve annulus to take place during the cardiac cycle, thus improving annular stress distribution and reducing the risk of ring dehiscence [45, 46]. Oppositely, rigid rings allow for sizing and shaping of the mitral annulus thus restricting its motion during the cardiac cycle and worsening annular stress distribution, thus contributing to a higher risk of dehiscence [44–47].

Our results also indicated lower dehiscence rates with semi-rigid when compared to rigid rings in mitral position. The difference has been explained in *in vitro* and *in vivo* studies based on the location of dehiscence occurrence [44]. Indeed, mitral ring dehiscence was found to be mostly located in the posterior segment of the mitral annulus, due to the segment being constituted of low-collagen muscular fibres, thus increasing the risk of dehiscence [13, 48]. Skov *et al.* [44] in their laboratory study found semi-rigid rings to have significantly lower deformational forces on the posterior segment of the annulus when compared to the rigid ring.

Biological rings made of autologous pericardium showed the highest dehiscence rate. Scarcity and inconsistency in data and techniques could explain the following results, which remain controversial. On the one hand, biological rings have been found to be independent predictors of MVR failure and reoperation, mainly due to insufficient provision of stability, durable fixation and remodelling of the annulus. However, differences in studies' outcomes could be explained through technical variations. Particularly, through twisting of the autologous pericardium Miura *et al.* [17] argue that a thicker and strengthened ring/band could be obtained, thus reducing the risk of dehiscence. Meticulous patient selection remains crucial in this cohort, as a severely dilated annulus would constitute a risk factor for recurrent MR. Infective endocarditis requires further exploration, Bevilacqua *et al.* [25] excluded IE patient (and reported dehiscence), while Miura *et al.* [17] included IE patients and did not report dehiscence.

In the tricuspid population, analysis was not possible as only 1 study out of 10, by Pfannmüller *et al.* comparing Cosgrove Edwards to Carpentier Edwards ring reported dehiscence among their patients [33]. Indeed, the remaining 9 studies reported no dehiscence occurrence, out which eight [29–32, 35–38] used a 3D rigid annuloplasty ring to repair the tricuspid valve. Izutani *et al.* [38] and Wang *et al.* [36] both carried comparative studies of 3D rigid rings with flexible rings. While they both did not report any dehiscence among their patients, they both found 3D rigid rings to be associated with a lower grade of postoperative tricuspid regurgitation and a lower recurrence of tricuspid regurgitation. These findings were explained through the 3D shape of the rigid ring being able to accommodate the saddle shape of the tricuspid annulus.

Dehiscence rate: ring size and shape

The results of our study did not demonstrate any significant difference in dehiscence rate by ring size, although they tended

towards significance ($P=0.067$), potentially illustrating that patients receiving larger rings could develop more dehiscence. This meta-regression analysis, however, was crude indicating the need for further assessment in future studies (Table 2). Similarly, no significant difference between full and partial rings was found. Currently, no clinical study exists exploring whether full or partial rings and smaller or larger rings could lead to changes in dehiscence rate. Indeed, the published literature is mostly constituted by a few preclinical studies only assessing the effects of ring under-sizing. It would be extremely difficult and subjective to determine retrospectively whether undersizing was performed or not, thus the analysis was not feasible. Nevertheless, the evidence within this area remains worth discussing.

In their laboratory study, Pierce *et al.* [42] compared normalized to undersized rings and found contractile forces on the sutures to be higher with undersized rings as they constricted the annulus. However, the contractile forces on the ring sutures were higher only on the anterior section of the annuloplasty ring, while no difference was found with respect to the posterior segment of the annulus. As previously mentioned, the posterior segment of the annulus is weaker than the anterior section, therefore also more commonly found to be dehisced. Nevertheless, the multivariable nature of the annuloplasty rings creates difficulties when drawing definitive conclusions and interpretation of findings should be made with caution. Indeed, undersizing has been commonly adopted and preferred for the repair of ischaemic mitral regurgitation, owing to its satisfactory acute haemodynamic outcomes. Nevertheless, it contributes to ventricular remodelling and an unphysiological configuration of the valve, causing a hyperextension of the anterior leaflet and vertical immobilization of the posterior leaflet, with both leaflets being tethered thus contributing pathological changes [49–51]. The pressure created during systole on the tethered leaflets pulls the annulus radially downwards, thus potentially increasing the risk of ring dehiscence.

Dehiscence and pathology

Our results comparing ring dehiscence rate by mitral regurgitation pathology revealed significantly higher rates in patients receiving mitral annuloplasty ring repair for ischaemic mitral regurgitation when compare to the non-ischaemic population (3.91% vs 1.64%). Persistent or recurrent MR following annuloplasty has been well documented in the literature, associating recurrent MR with continued left ventricular remodelling in ischaemic MR [49, 50]. Due to the progressive nature of left ventricular remodelling, the initial annular compensation offered by ring annuloplasty might not be durable. Annuloplasty alone only offers a solution for annular tethering while not fully addressing the ventricular aspect, therefore being associated with worsening and recurrent MR [50, 51]. The weakened and calcified annular tissue found in ischaemic mitral regurgitation together with more aggressive annular downsizing contributes to creating a clinical picture that exposes the annulus-ring system to greater stresses, thus increasing the risk of dehiscence [3, 50, 51].

Further comments

Annuloplasty ring dehiscence is the result of diverse factors, not all of them being necessarily associated to ring or pathology-related characteristics. Similarly, the degree of impact of ring and

pathological factors, while significant in some instances (as shown in our analysis), should not be thought to be superior to the impact of operator's experience and technical operative choices. Noack *et al.* [13] found that in the 2nd period of their study (2006–2016), the reported rate of ring dehiscence decreased when compared to the 1st period (1996–2005), attributing it to the increased experience of the centre and improvement in MV repair techniques and ring technology throughout the years. Indeed, the operator can play a role both in the choice of suboptimal treatment strategies, for instance performing valve repair instead of replacement, and on a technical level. Suture misplacement, as well as variations in suture bite depth, width and height have been all associated with dehiscence development. In the setting of tricuspid repair, Pfannmüller *et al.* [33] mention shallow suture placement around the septal annulus being caused by the less experienced surgeon's fear of causing atrioventricular block.

When performing mitral or tricuspid annuloplasty ring repair a simple technique with placement of sutures parallel to the annulus is routinely performed. In particular circumstances, such as in cases of ischaemic MR or tricuspid regurgitation where aggressive annular downsizing is performed, the annulus-ring system and its sutures might encounter increased stresses and radial forces, thus increasing the risk of ring dehiscence. Nevertheless, as previously described in the literature for mitral valve replacement, a potential benefit in the use of pledget suture might exist [52]. The use of supra-annular pledgets placed radially and circumferentially in annuloplasty ring repair might potentially reduce the risk of dehiscence by providing increased stability to the ring [53]. A potential alternative approach to increase stability and heterogenous distribution of tensile forces, thus reducing the risk of dehiscence, would be annular remodelling from commissure to commissure along the postero-lateral portion of the annulus through the use of a strip of glutaraldehyde-treated autologous pericardium with a continuous suture of monofilament material, a similar successful use was reported by Miura *et al.* [17].

Limitations

There are several limitations in both our study design and reporting of outcomes that impact the interpretation of our results. Firstly, a very limited number of direct comparative studies exist between different types of rings, with no comparative studies looking at the other factors analysed. Secondly, inter-studies variations in patient baseline characteristics, intraoperative and follow-up characteristics should be considered when interpreting the data as they could influence the results of the pooled analysis. Due to the lack of comparative studies and studies focusing on ring dehiscence as part of primary or secondary outcomes, a meta-analysis is not feasible, thus only allowing us to carry out a pooled analysis. Furthermore, an analysis of other possible predisposing factors for dehiscence such as positioning of sutures (parallel, perpendicular to the ring), suture material, minimally invasive vs open approach and teaching hospital was not possible due to absence of dehiscence-related data.

CONCLUSION

Annuloplasty ring dehiscence remains a rare but severe complication of heart valve surgery. In mitral annuloplasty ring repair,

dehiscence rate has been found to significantly vary across types of rings, with rigid ring leading to more elevated rates when compared to flexible rings. Our study did not find ring size and shape to be associated with changes in dehiscence rate. Furthermore, ischaemic regurgitation was associated with higher rates of dehiscence in mitral annuloplasty when compared to non-ischaemic MR.

It is of utmost importance to underline that the operative outcomes in clinical practice are not solely determined by the choice of ring type but by a multiple clinical and patients-related factors. Understanding this multifactorial nature of ring dehiscence will help in identifying the patients at high risk and improve their clinical outcomes. Nevertheless, annuloplasty ring dehiscence remains a serious complication associated with poor repair outcomes. Large-scale randomized clinical trials are needed to assess the impact of multifactorial risk factors on the development of ring dehiscence, thus leading to the development of adequate treatment guidelines for this category of patients.

SUPPLEMENTARY MATERIAL

Supplementary material is available at *EJCTS* online.

Conflict of interest: none declared.

Author contributions

Arian Arjomandi Rad: Data curation; Formal analysis; Investigation; Methodology; Validation; Visualization; Writing—original draft; Writing—review & editing. **Vinci Naruka:** Data curation; Formal analysis; Methodology; Supervision; Validation; Writing—original draft; Writing—review & editing. **Robert Vardanyan:** Formal analysis; Methodology; Validation; Writing—original draft; Writing—review & editing. **Alessandro Viviano:** Data curation; Supervision; Validation; Writing—review & editing. **Mohammad Yousuf Salmasi:** Data curation; Formal analysis; Methodology; Validation; Writing—review & editing. **Dimitrios Magouliotis:** Data curation; Validation; Writing—review & editing. **Simon Kendall:** conceptualization; Supervision; Validation; Visualization; Writing—review & editing. **Roberto Casula:** Conceptualization; Supervision; Validation; Visualization; Writing—review & editing. **Thanos Athanasiou:** Conceptualization; Data curation; Methodology; Project administration; Supervision; Writing—original draft; Writing—review & editing.

Reviewer information

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