Tricuspid valve
and
Pacing leads

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Cardiac Implantable Electronic Device Lead-Induced Tricuspid Regurgitation

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JACC: CARDIOVASCULAR IMAGING

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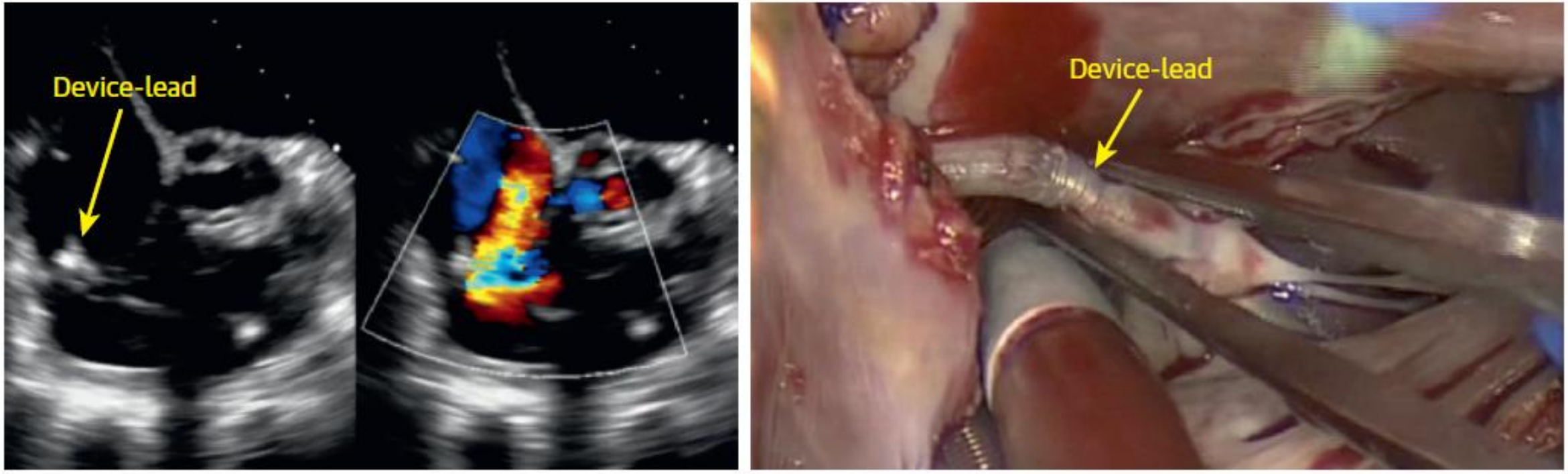
FIGURE 1 Patient With Device Lead-Induced TR



On 2D **(left)** and color Doppler **(middle)** views, the device leads can be seen traversing the TV **(left)** and a significant amount of TR is seen on the 2D color Doppler image. The location of TR suggests that the device lead may be interfering with leaflet motion. Intraoperative view **(right)** shows that the device lead is entrapped by fibrous/inflammatory tissue and is adhering to the TV leaflets and subvalvular apparatus. See Video 1. TR = tricuspid regurgitation; TV = tricuspid valve.

Background

730 000 New PM and 330 000 ICDs in 2009

7 to 45% TR post implantation (New onset/worsening)

TABLE 1 Frequency of CIED-Related Tricuspid Regurgitation

First Author (Ref. #)	Year	N	CIED	Timing of TR Assessment After Implantation	Assessment of Onset or Worsening of TR	Reported Frequency, %	Comments
Paniagua et al. (15)	1998	374	All PPM	NA	Onset	7	Severe TR was defined as 3 to 4+ TR
de Cock et al. (8)	2000	96	All PPM	Mean: 7.4 ± 2 yrs	Onset	21	Severity of TR was not specified
Seo et al. (16)	2008	87 (TR data available only in 82)	50 PPM, 17 ICD, 20 CRT	Range: 0 to 240 months	Onset	15	10 of the 12 patients who developed severe TR had nonsevere TR prior to CIED implantation
Kim et al. (12)	2008	248	174 PPM, 74 ICD	Range: 23 to 199 days	Worsening by at least 1 grade	24	21.2% of patients developed new, clinically significant TR (1.5 to 3+)
Webster et al. (17)	2008	123	All PPM	Median: 827 days	Worsening by at least 1 grade	25	Study population consisted of pediatric and congenital heart disease patients
Klutstein et al. (13)	2009	410	All PPM	Range: 1 to 3,549 days	Worsening by at least 2 grades	18	Improvement by at least 2 grades was observed in 4.4%
Höke et al. (11)	2014	239	191 ICD, 48 PPM	Within 1.5 yrs	Worsening to a grade ≥2	38	Significant TR was defined as grade ≥2
Fanari et al. (64)	2015	206	120 PPM, 86 ICD	Mean: 29 ± 19 months	Worsening by at least 1 grade	45	Post-implantation echocardiography was performed at least 6 months after lead insertion
Lee et al. (14)	2015	382	203 PPM, 179 ICD	Range: 1-1,200 days	Worsening by at least 2 grades	10	TR was assessed on a 6-point scale
Arabi et al. (6)	2015	41	7 PPM, 25 ICD, 9 CRT	1, 6, and 12 months	Worsening by at least 2 grades	17	TR was worsening by 1 grade in 71% of patients
Al-Bawardy et al. (5)	2015	1,596	611 PPM, 985 ICD	Range: 1 day-6.5 yrs	Prevalence of severe TR at 4 yrs	35	Prevalence of severe TR pre-implantation was 27%
Delling et al. (9)	2016	634	All PPM	NA	Onset	16	Significant TR was defined as ≥3+

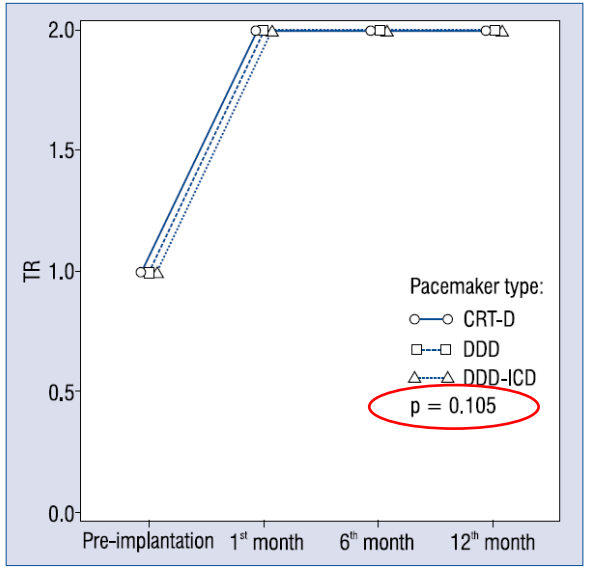
Higher occurrence for **ICD lead** ?

Table 2 Worsening by one tricuspid regurgitation grade or more

	PPM group		ICD group		
	Total (n)	% TR increase (n)	Total (n)	% TR increase (n)	*P*
Total	174	20.7% (36)	74	32.4% (24)	.048
TR 0-1	127	25.2% (32)	52	34.6% (18)	.200
TR 1.5-3	47	8.5% (4)	22	27.2% (6)	.040

ICD, Implantable cardioverter defibrillator; *PPM*, permanent pacemaker; *TR*, tricuspid regurgitation.

Kim JB et al. J Am Soc Echocardiogr 2008;21:284-7



Effects of pacemaker and implantable cardioverter defibrillator electrodes on tricuspid regurgitation and right sided heart functions

Peyman Arabi[1], Necla Özer[1], Ahmet Hakan Ateş[2], Hikmet Yorgun[1], Ali Oto[1], Kudret Aytemir[1]

Figure 1. Change in tricuspid regurgitation (TR) between cardiac device types assessed by color flow jet.

Cardiology Journal
2015, Vol. 22, No. 6, 637–644

Background

Pacing could improve RV hemodynamics parameters

Tricuspid Regurgitation Following Implantation of Endocardial Leads: Incidence and Predictors

REGINA C. LEE, M.D.,* SCOTT E. FRIEDMAN, M.D.,†,‡ ALAN T. KONO, M.D.,‡ MARK L. GREENBERG, M.D.,† and ROBERT T. PALAC, M.D.*

PACE 2015; 38:1267–1274

Conflicting data and low level of evidence

- Retrospective – observational and non randomised studies
- Small cohort
- TR assessment on 2D TTE (lead acoustic artifact, lead through TV annulus seen in 15% of patients)
- Patients with CRT/ICD and LV dysfunction : RV/Tricuspid annulus enlargement

patients undergoing surgery for device lead-mediated TR
37% had TR underestimated on TTE compared to intraoperative TEE

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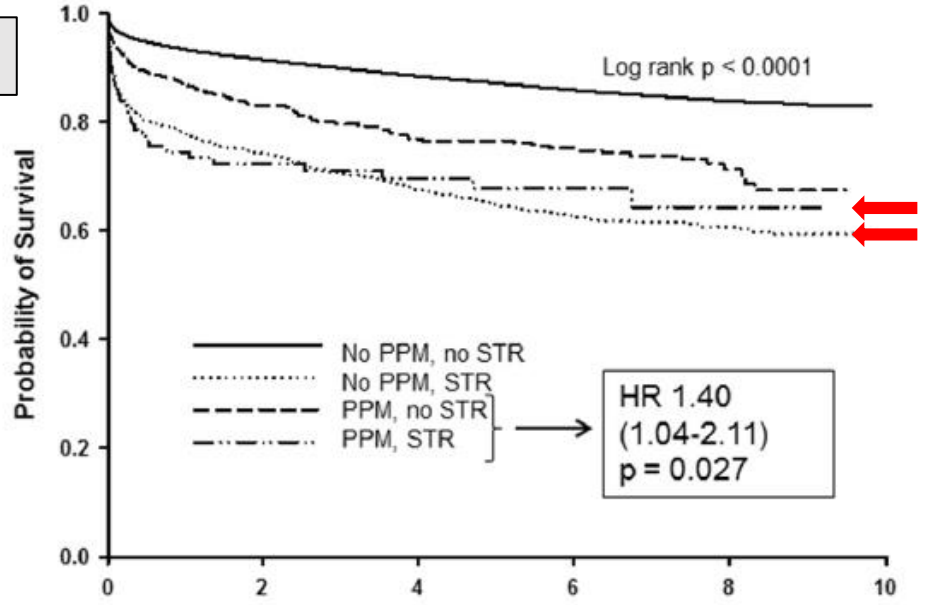
Published by Elsevier Inc.
doi:10.1016/j.jacc.2005.02.037

Heart Rhythm Disorders

Severe Symptomatic Tricuspid Valve Regurgitation Due to Permanent Pacemaker or Implantable Cardioverter-Defibrillator Leads

Grace Lin, MD,* Rick A. Nishimura, MD, FACC,* Heidi M. Connolly, MD, FACC,* Joseph A. Dearani, MD,† Thoralf M. Sundt III, MD,† David L. Hayes, MD, FACC*
Rochester, Minnesota

TR lead-mediated OUTCOMES



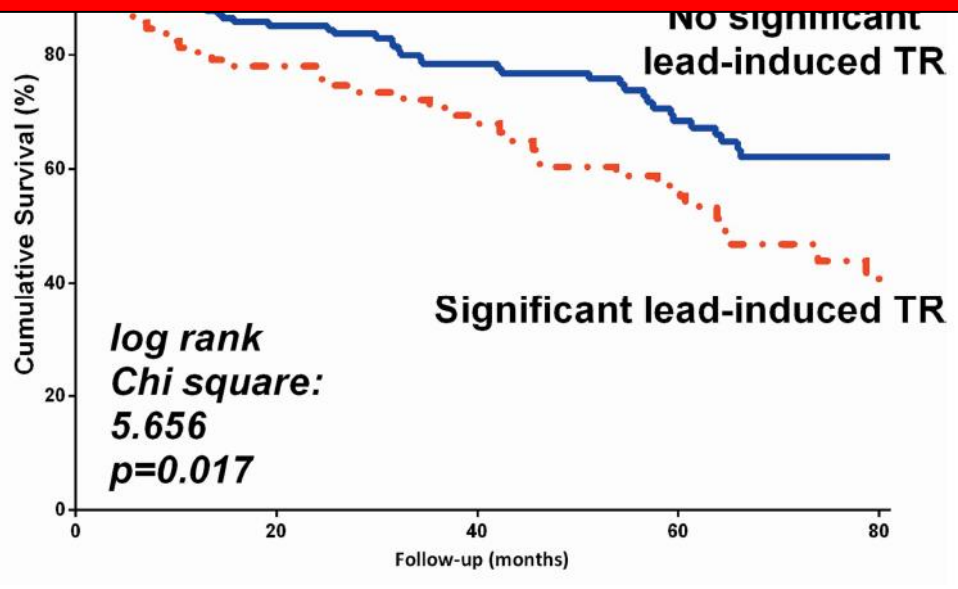
Tricuspid Regurgitation and Mortality in Patients With Transvenous Permanent Pacemaker Leads

Francesca N. Delling, MD[a,b,*], Zena K. Hassan, MD[c], Gail Piatkowski, BSBC[d], Connie W. Tsao, MD[a,b], Alefiyah Rajabali, MD[a,b], Lawrence J. Markson, MD, MPH[e], Peter J. Zimetbaum, MD[a,b], Warren J. Manning, MD[a,b,f], James D. Chang, MD[a,b], and Kenneth J. Mukamal, MD[a]

Am J Cardiol 2016;117:988–992

Significative TR

STOP PM/ICD IMPLANTATION IS NOT A OPTION
BETTER UNDERSTANDING LEAD-RELATED TR



Significant lead-induced tricuspid regurgitation is associated with poor prognosis at long-term follow-up

Höke U, *et al*. *Heart* 2014;**100**:960–968. doi:10.1136/heartjnl-2013-304673

Mortality + Heart Failure

Predict lead-mediated TR ?

Significant lead-induced tricuspid regurgitation is associated with poor prognosis at long-term follow-up

Multivariate Analysis of Increased TR Predictors

	Odds Ratio	95% Confidence Interval	P Value
Age	1.01	0.97–1.06	0.53
Male sex	0.82	0.27–2.48	0.73
Predevice atrial fibrillation	0.76	0.25–2.26	0.62
PPM versus ICD	0.44	0.10–2.00	0.29
Ejection fraction	0.99	0.96–1.04	0.93
LA area	0.97	0.89–1.06	0.54
RA area	1.15	1.06–1.25	**0.001**
RV systolic pressure	1.06	1.01–1.11	**0.015**
Mitral regurgitation	1.62	0.51–5.12	0.41

Höke U, *et al*. *Heart* 2014;**100**:960–968. doi:10.1136/heartjnl-2013-304673

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Table 2
Multivariable regression analysis to predict significant tricuspid regurgitation within the permanent pacemaker group

Variable	OR	95% CI	*P* value
Age (per 10 years)	1.50	1.06-2.13	0.02
BMI (per 5 kg/m^2)	0.71	0.54-0.95	0.02
Heart rate (per 10 beats/min)	1.17	1.01-1.36	0.04
Right ventricular dilatation	5.32	2.86-9.81	<.0001
PASP ≥ 37 mmHg	2.16	1.31-3.56	0.003
MV repair or replacement	3.71	1.61-8.55	0.002
Mitral regurgitation ≥ 3+	1.70	1.01-2.35	<.0001

Am J Cardiol 2016;117:988–992

Tricuspid Regurgitation Following Implantation of Endocardial Leads: Incidence and Predictors

REGINA C. LEE, M.D.,* SCOTT E. FRIEDMAN, M.D.,†,‡ ALAN T. KONO, M.D.,‡ MARK L. GREENBERG, M.D.,† and ROBERT T. PALAC, M.D.*

PACE 2015; 38:1267–1274

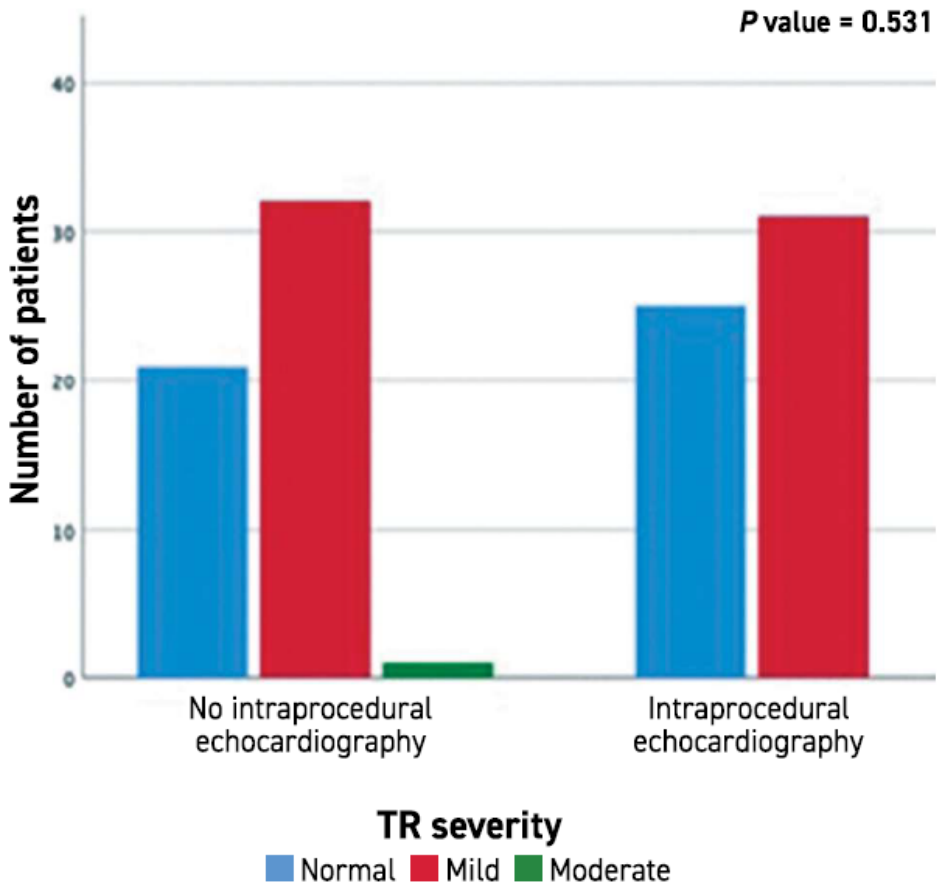
No significant differences between TR – noTR patients

Echocardiography-guided Cardiac Implantable Electronic Device Implantation to Reduce Device Related Tricuspid Regurgitation: A Prospective Controlled Study

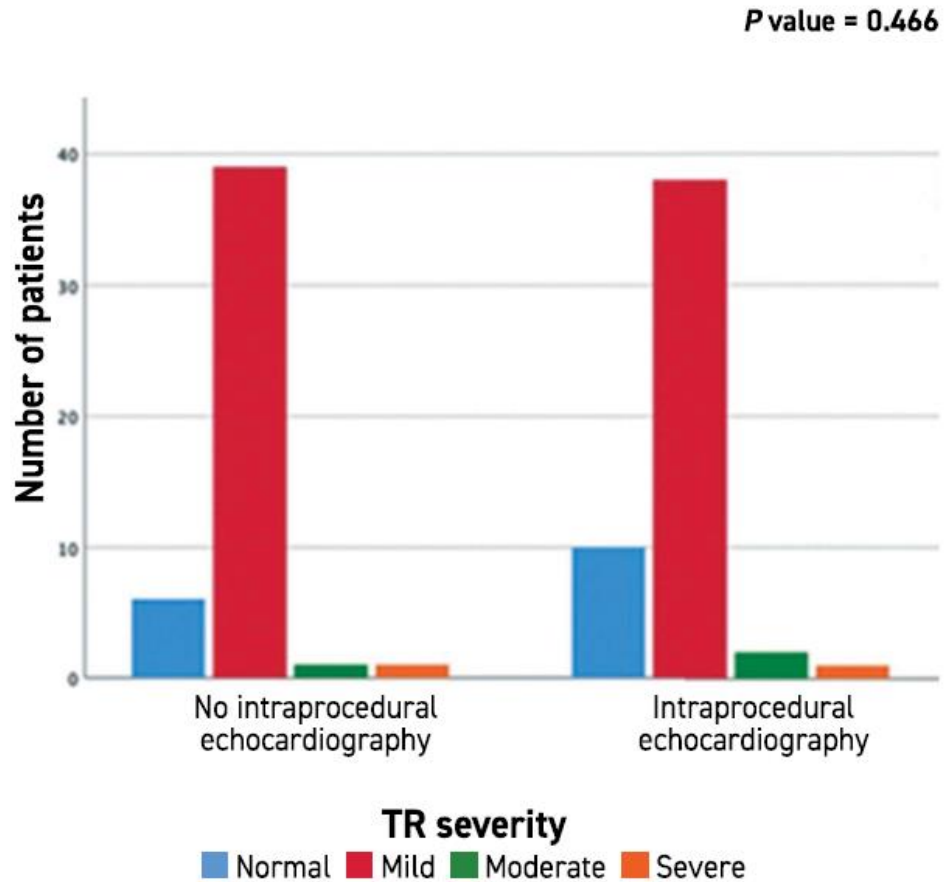
Gergana Marincheva MD*, Tal Levi MD*, Olga Perelshtein Brezinov MD, Andrei Valdman MD, Michael Rahkovich MD, Yonatan Kogan MD, and Avishag Laish-Farkash MD PhD

Electrophysiology and Pacing Unit, Department of Cardiology, Assuta Ashdod University Medical Center Ben Gurion University of the Negev, Beer Sheva, Israel

[A] Baseline



[B] After 3 to 6 months follow-up



Natural history of TR : time relation to implantation

Effects of pacemaker and implantable cardioverter defibrillator electrodes on tricuspid regurgitation and right sided heart functions

Peyman Arabi[1], Necla Özer[1], Ahmet Hakan Ateş[2], Hikmet Yorgun[1], Ali Oto[1], Kudret Aytemir[1]

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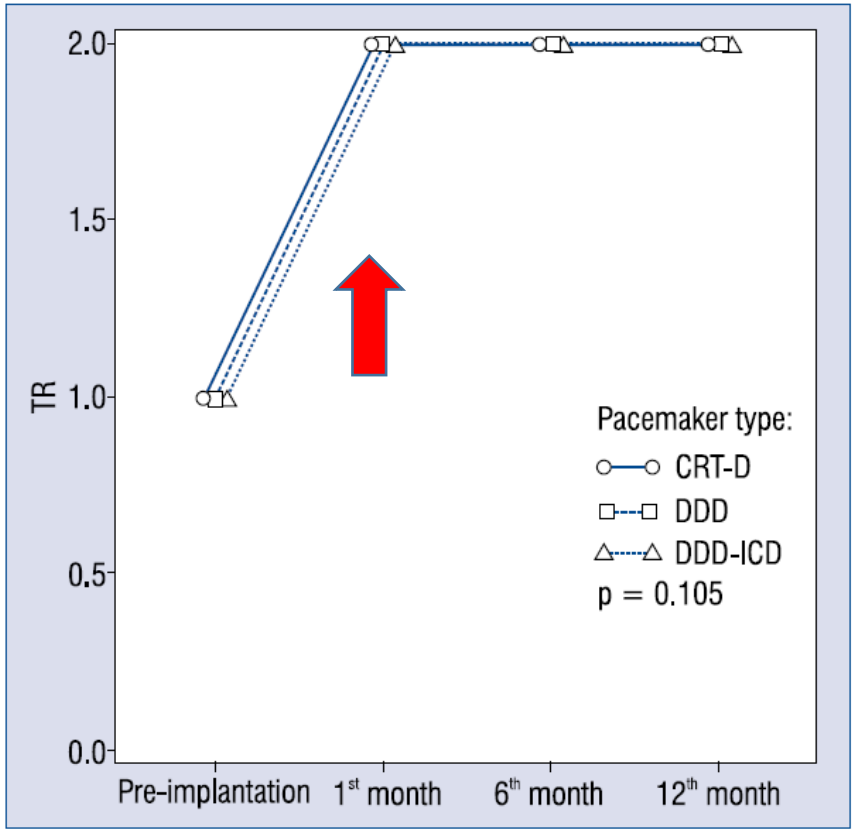


Figure 1. Change in tricuspid regurgitation (TR) between cardiac device types assessed by color flow jet.

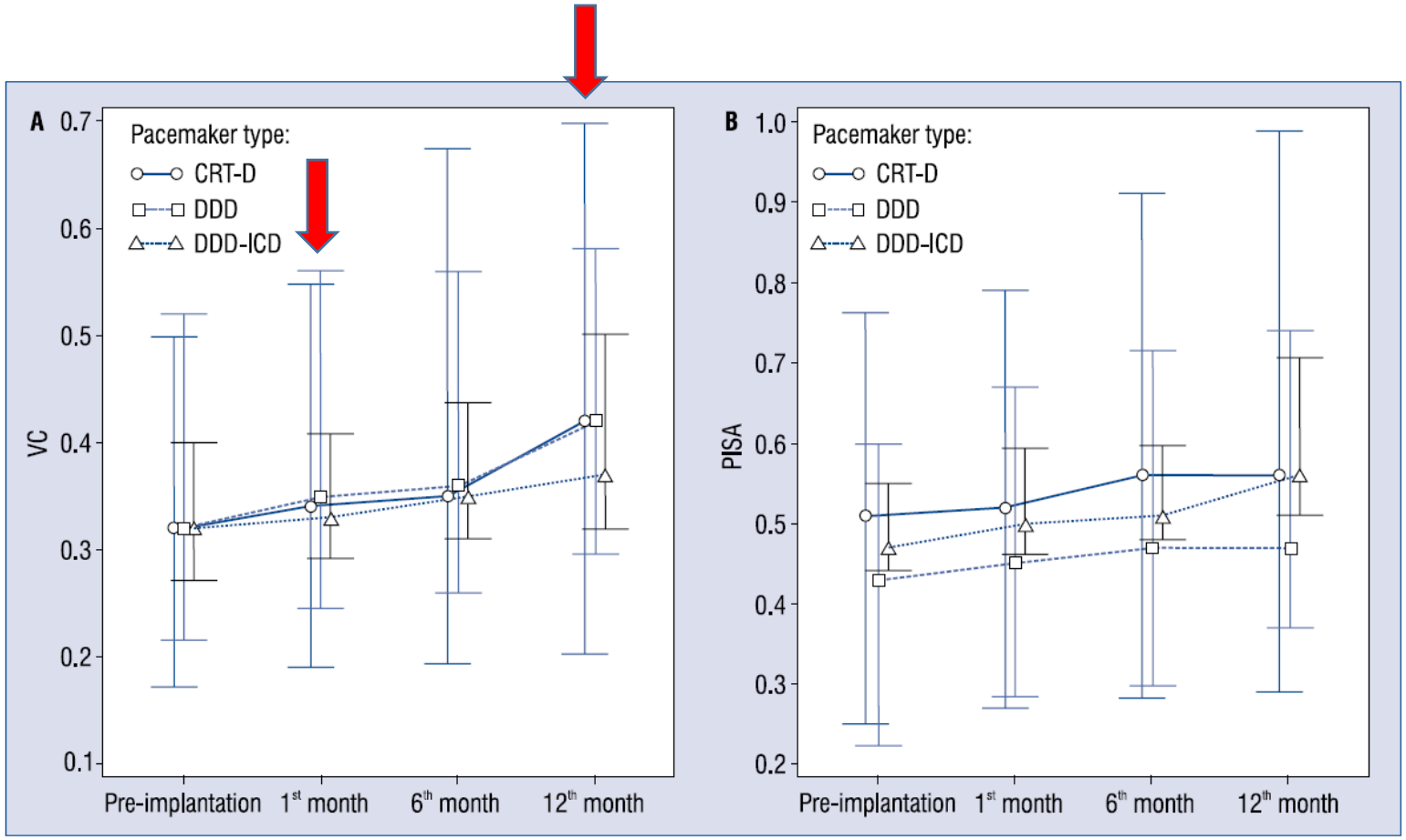


Figure 2. Change in vena contracta (VC) (**A**) and proximal isovelocity surface area (PISA) (**B**) during the follow-up compared to basal levels for all cardiac device types ($p < 0.005$ between preimplantation and 12th month for both VC and PISA).

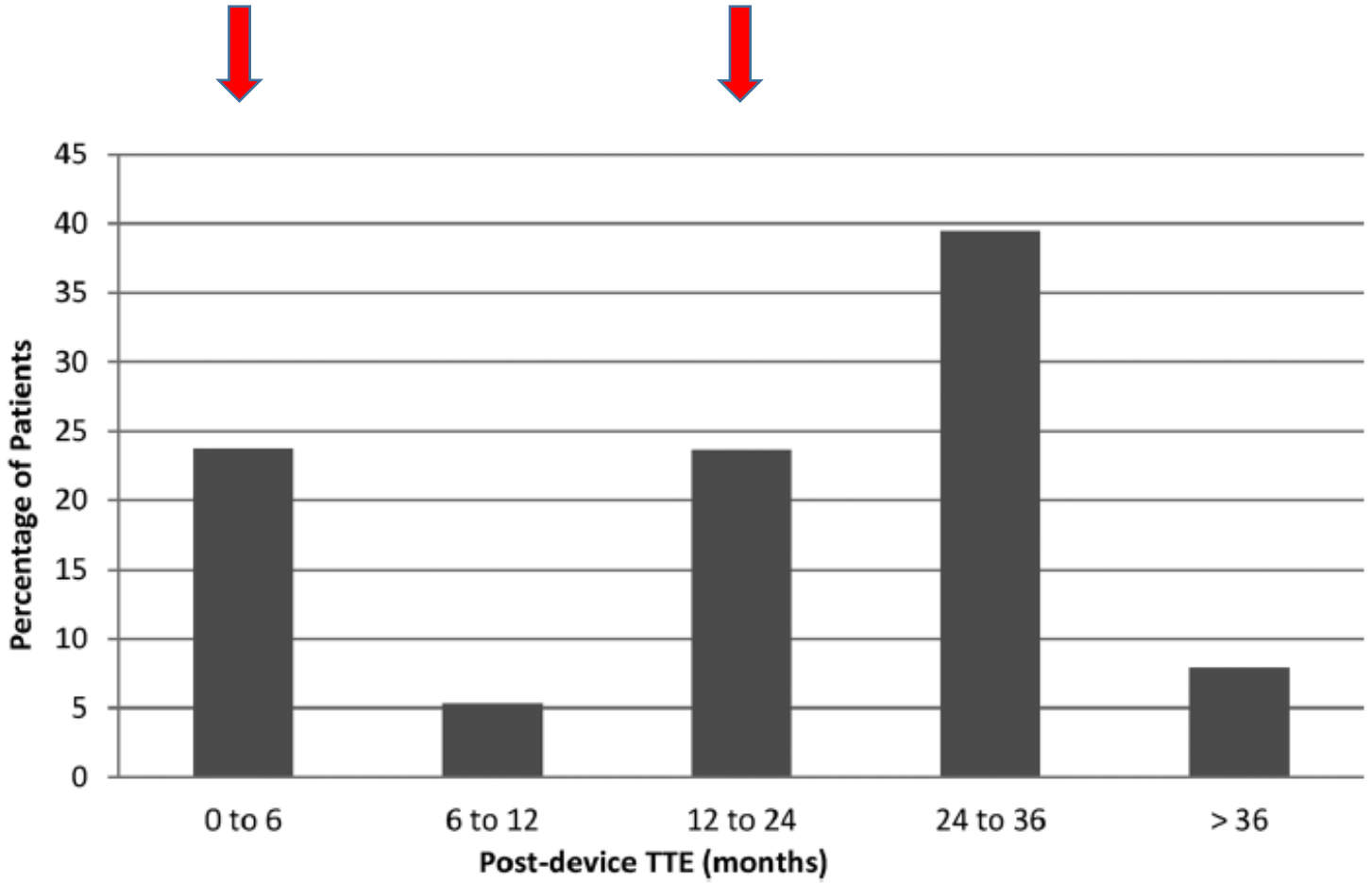
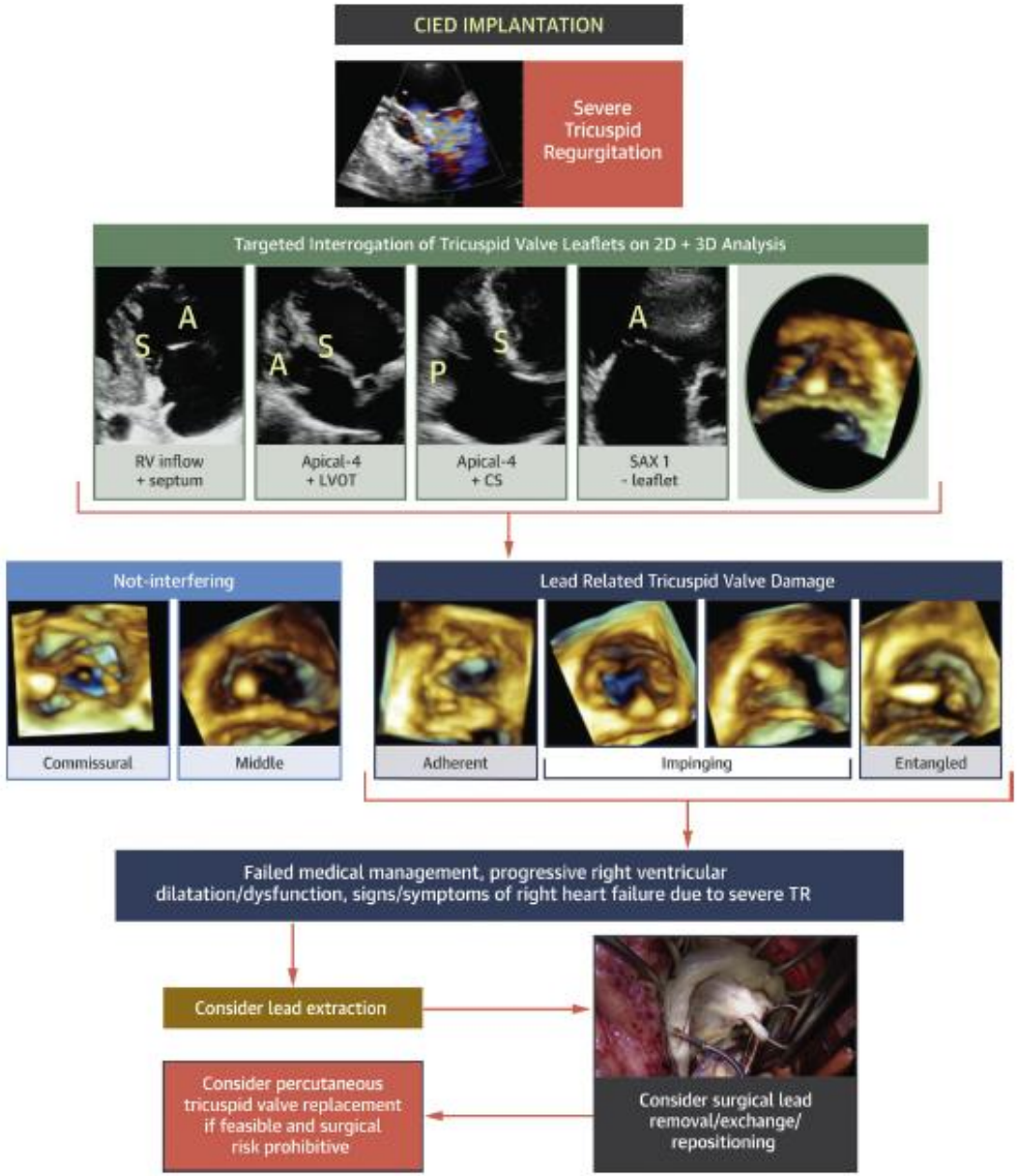


Figure 3. *Percentage of patients with 2+ grade worsening tricuspid regurgitation capture per postdevice echocardiogram interval. TTE = transthoracic echocardiogram.*

CENTRAL ILLUSTRATION Pictorial Representation of Possible Decision Pathway for a Patient Who Presented With Severe Tricuspid Regurgitation in the Presence of a Device Lead



Addetia, K. et al. J Am Coll Cardiol Img. 2019;12(4):622-36.

TR Diagnosis

↓

Lead Related TR ? : TTE/TEE 2D/3D

↓

Assess consequences
- HF
- RV

Medical therapy : Diuretic agents

Percutaneous lead **extraction**

Surgical lead **extraction** (+ TV repair) vs.
Percutaneous TV repair

Alternative Pacing system : Leadless, CS, epicardial

Percutaneous lead **extraction**

No guidelines in the absence of lead/device infection

Potential TV damage and worsening TR

A Study of Major and Minor Complications of 1500 Transvenous Lead Extraction Procedures Performed with Optimal Safety at Two High-Volume Referral Centers

Int. J. Environ. Res. Public Health **2021**, *18*, 10416.

Minor complication : TR increase ≤ 2 degrees and < grade 4 = **2.91%**
Major complication : TR increase >2 degrees or grade 4 = **0.81%**

Non-powered mechanical lead extraction

Changes in TR after TLE

Direction of changes in TR	No. of patients	%
No changes	1175	79.61%
Increase by 1 degree	106	7.18%
Increase by 2 degrees	35	2.37%
Increase by 3 degrees	8	0.542%
Decrease by 1 degree	131	8.87%
Decrease by 2 degrees	21	1.42%

90% of patients
No changes
or
Decrease of TR

The Impact of Transvenous Lead Extraction on Tricuspid Valve Function

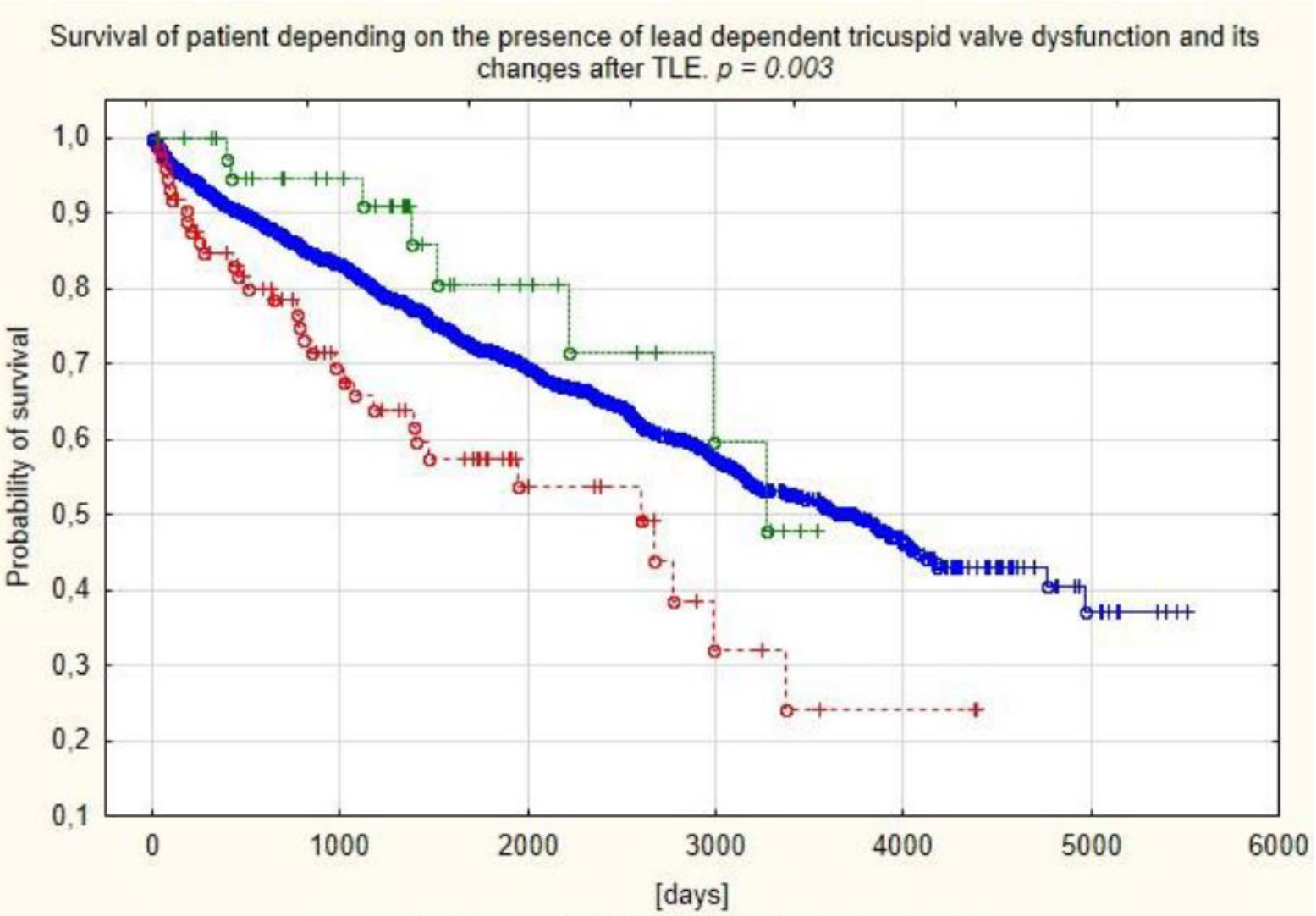
PACE 2014; 37:19–24

Difference in Tricuspid Regurgitation Score Postlead Extraction Stratified by Patient and Device Characteristics

Characteristics	Number of Patients N (%)	Difference in TR Score Post Lead Extraction*	95% CI	P value
All Patients	124 (100)	+0.18	−0.03 to 0.39	0.11
Gender				
Male	80 (65)	+0.13	−0.11 to 0.36	0.31
Female	44 (35)	+0.27	−0.15 to 0.70	0.21
Age				
Age ≥ 75	42 (34)	+0.45	0.07 to 0.83	0.02
Age < 75	82 (66)	+0.04	−0.13 to 0.30	0.78
Diabetes Mellitus				
Yes	29 (23)	+0.31	−0.09 to 0.72	0.13
No	95 (87)	+0.14	−0.12 to 0.39	0.29
CHF				
Yes	81 (65)	+0.10	−0.13 to 0.32	0.39
No	43 (35)	+0.33	−0.14 to 0.79	0.17
Device				
Pacemaker	26 (21)	+0.54	−0.15 to 1.24	0.12
AICD	98 (79)	+0.08	−0.12 to 0.29	0.44
Number of Leads				
1	71 (57)	+0.14	−0.21 to 0.24	0.90
≥2	53 (43)	+0.40	0–0.81	0.05
Lead Site				
RA	2 (2)	+0.03	−0.20 to .258	0.50
RV	66 (53)	−0.01	−0.24 to 0.22	0.89
LV	3 (2)	+0.33	−1.10 to 1.76	0.42
RA + RV	32 (26)	+0.44	−0.15 to 1.03	0.14
RA + LV	0 (0)	–	–	–
LV + RV	1 (1)	+2	–	–
RA + LV + RV	20 (16)	+0.40	−0.13 to 0.93	0.13
Lead Age†				
0–24 months	45 (49)	+0.16	−0.15 to 0.46	0.31
24–48 months	28 (30)	−0.28	−0.63 to 0.06	0.10
48–72 months	14 (15)	+0.28	−0.63 to 1.20	0.51
≥72 months	5 (6)	+1	0.12–1.87	0.03
Extraction Method				
Manual	65 (52)	+0.03	−0.29 to 0.35	0.85
Laser	59 (48)	+0.34	0.05–0.62	0.02
Indication for Extraction				
Device/lead failure	57 (46)	+0.14	−0.14 to 0.42	0.32
Infection	48 (39)	+0.21	−0.20 to 0.61	0.31
Other	19 (15)	+0.21	−0.33 to 0.75	0.42

Lead Dependent Tricuspid Valve Dysfunction-Risk Factors, Improvement after Transvenous Lead Extraction and Long-Term Prognosis

J. Clin. Med. **2022**, *11*, 89.



LDTVD (-) ---- LDTVD (+) non changed after TLE
------ LDTVD (+) improvement after TLE

35% of patients TR improvement after TLE

Surgical treatment of lead-related TR

No clear indications for severe primary TR without left sided disease

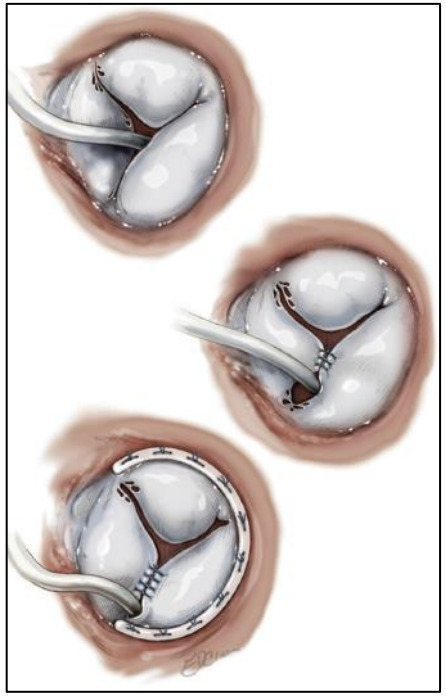
Should address both the valve and the lead

TV repair (Annuloplasty) vs. TV replacement if extensive damage

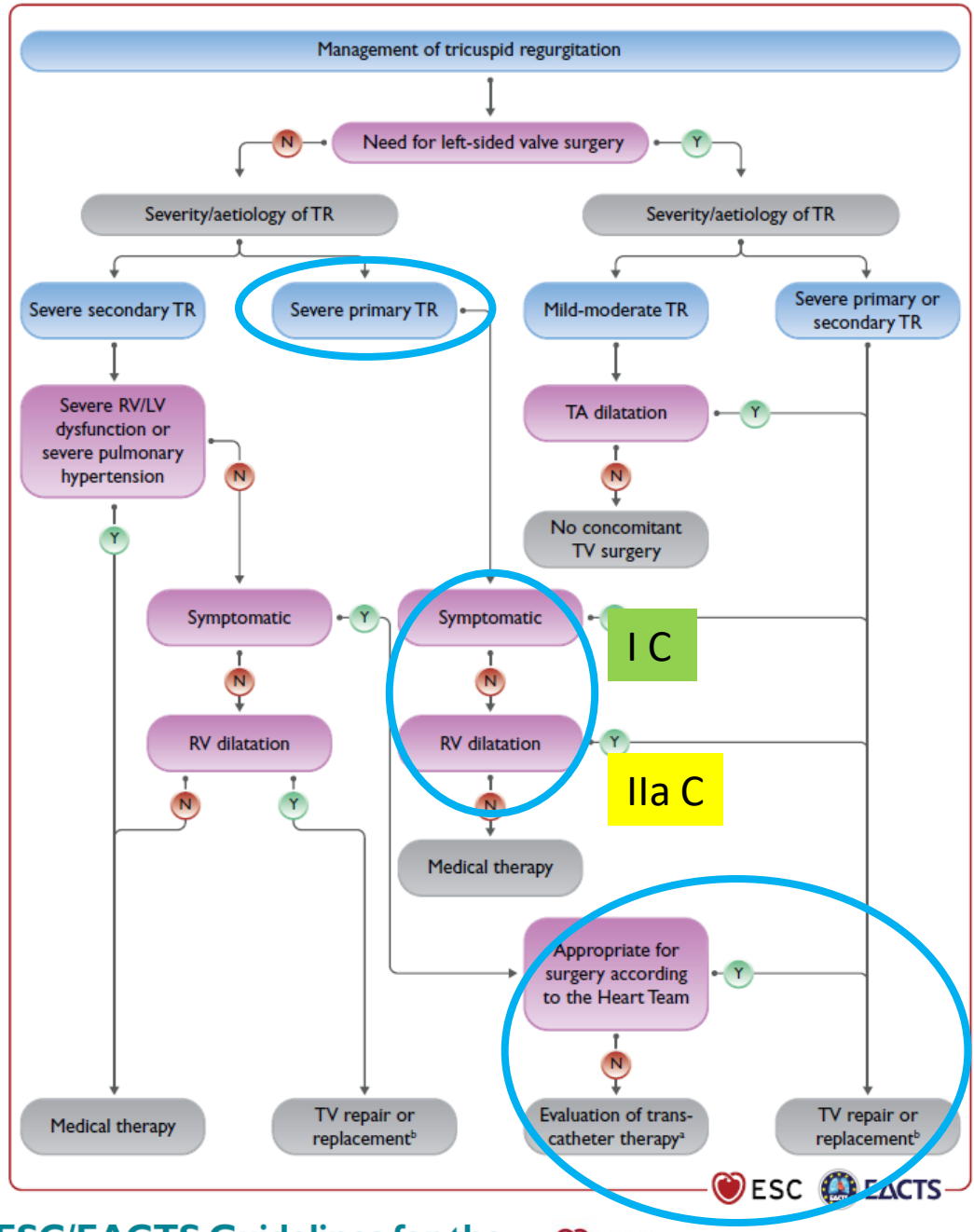
Lead management : epicardial implantation vs. Lead repositionning

Complex Tricuspid Valve Repair in Patients With Pacer Defibrillator–Related Tricuspid Regurgitation

Ann Thorac Surg 2016;101:1599–601



Securing the lead in the commissure between 2 leaflets (posterior/septal) without interfering with TV function



2021 ESC/EACTS Guidelines for the management of valvular heart disease

ESC European Society of Cardiology
European Heart Journal (2022) 43, 561–632
https://doi.org/10.1093/eurheartj/ehab395

Percutaneous TV repair

Indication for functional TR

PM/ICD patients excluded from studies

To consider for patients for whom :
- Symptomatic/RV dilatation due to severe TR
- Medical therapy failed
- Not a surgical candidate

Table 1. Baseline Characteristics of the Study Population

Implanted pacemaker, n (%)	64/64	19 (30)
Atrial fibrillation/atrial flutter, n (%)	63/64	54 (84)

ORIGINAL RESEARCH ARTICLE

Transcatheter Treatment of Severe Tricuspid Regurgitation With the Edge-to-Edge MitraClip Technique

Circulation. 2017;135:1802–1814.

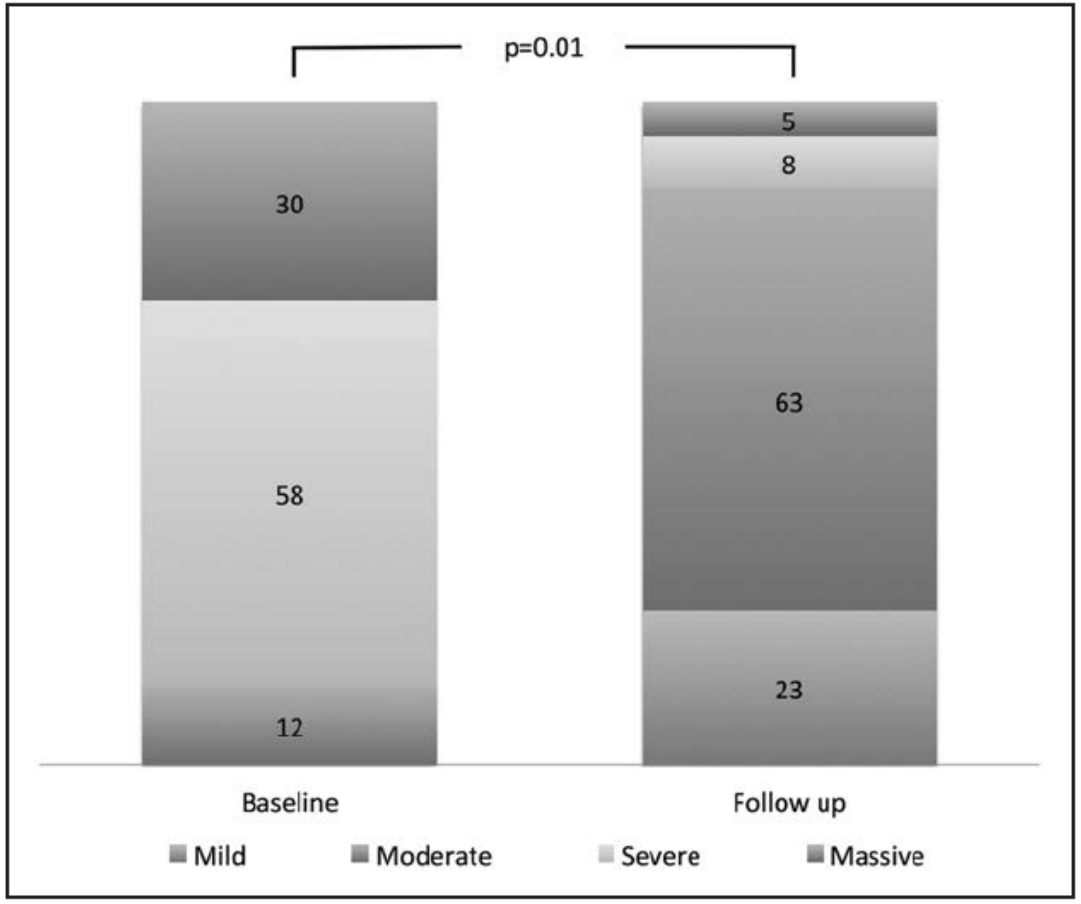
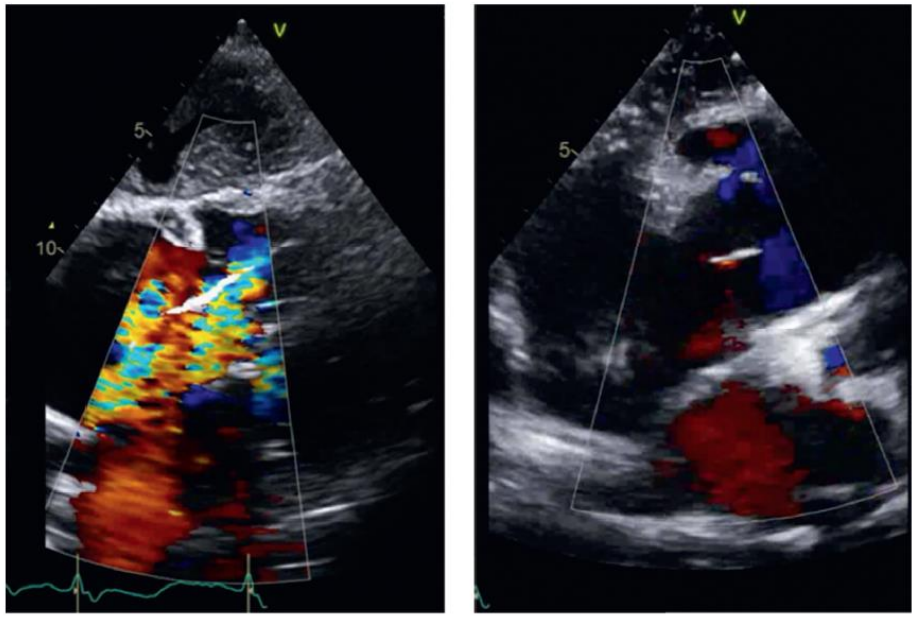
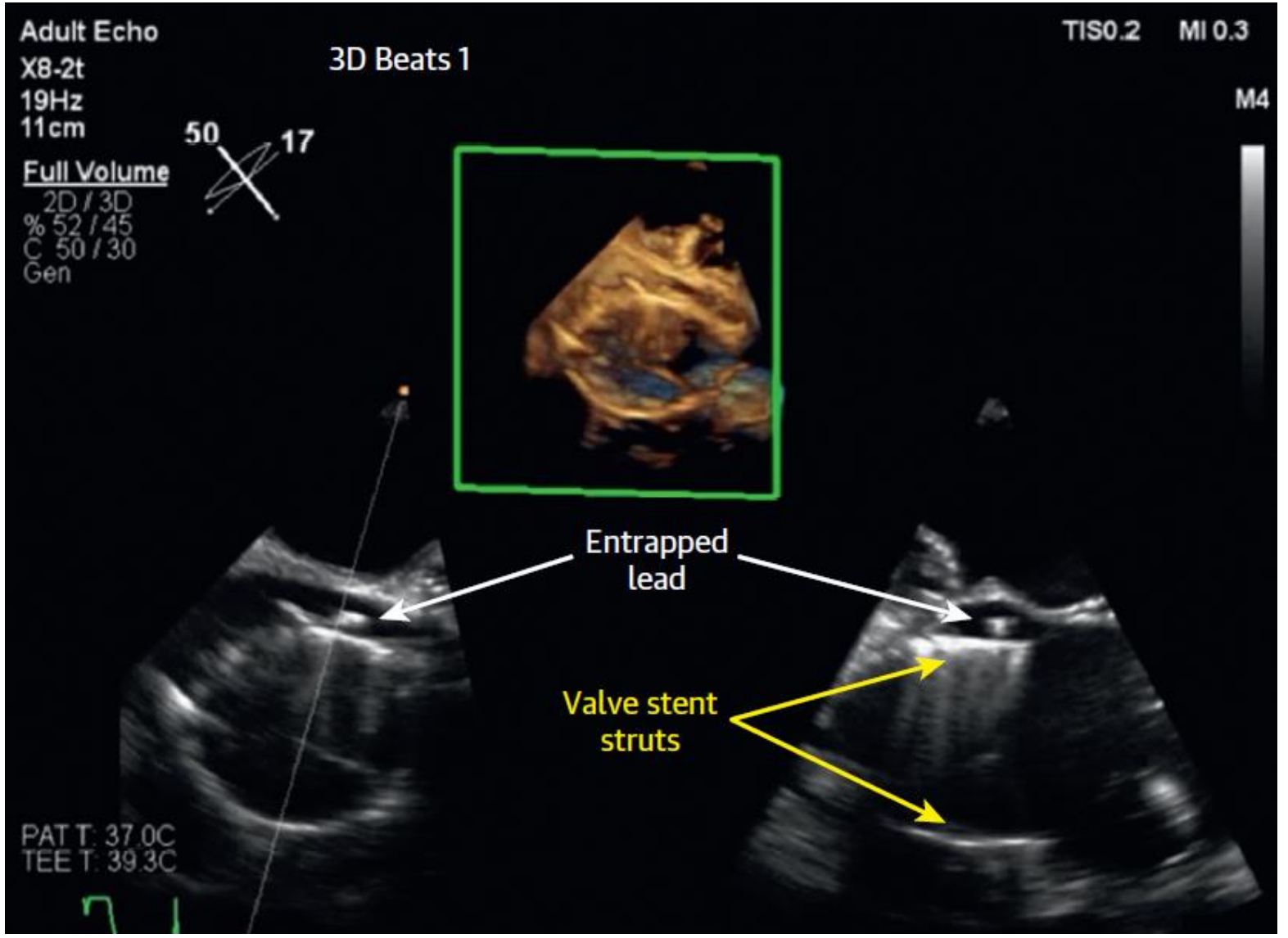


Figure 5. Stapled columns diagram of tricuspid regurgitation grades at baseline and before discharge.

FIGURE 8 Pre- and Post-TTVR





(Top left) Subcostal 4-chamber transthoracic echocardiogram view prior to transcatheter TV replacement showing severe lead-related TR. **(Top right)** Similar view after TTVR displaying the valve newly implanted with significant improvement in TR severity. **(Bottom)** Intra-procedural 3D transesophageal echocardiogram shows the relationship between the newly implanted valve stent struts and the entrapped pacemaker lead. See Video 7. TTVR = transcatheter tricuspid valve-in-valve replacement; other abbreviations as n Figure 1.

ESC European Society of Cardiology
Europace (2018) **20**, 823–828
doi:10.1093/europace/eux101

Right ventricular and tricuspid valve function in patients chronically implanted with leadless pacemakers

Erwan Salaun[1], Lilith Tovmassian[1], Blandine Simonnet[1], Roch Giorgi[2,3,4], Frédéric Franceschi[1], Linda Koutbi-Franceschi[1], Jérôme Hourdain[1], Gilbert Habib[1], and Jean-Claude Deharo[1]*

Table 2 Echocardiographic parameters before implantation, at discharge and 2-months after the implantation of the leadless device in the global cohort

Echocardiographic parameters	Before implantation (*N* = 23)	Hospital discharge (*N* = 23)	Two-month follow-up (*N* = 22)	*P*-value[a]
Tricuspid valve				
Tricuspid regurgitation				0.82
None or mild	17	18	16	
Moderate	6	5	6	
Severe	0	0	0	
Tricuspid annulus size (mm)	35.2 ± 7.0	36.6 ± 5.9	36.0 ± 6.1	0.35

Table 4 Right ventricular and tricuspid valve echocardiographic parameters before implantation, at discharge and 2-months after the implantation according to the position of the leadless device

Echocardiographic parameters	Septo-apical				Non septo-apical			
	Before implant (*N* = 10)	Hospital discharge (*N* = 10)	Two-month follow-up (*N* = 9)	*P*-value[a]	Before implant (*N* = 13)	Hospital discharge (*N* = 13)	Two-month follow-up (*N* = 13)	*P*-value[a]
Tricuspid valve								
Tricuspid regurgitation				1				0.72
None or mild	6	6	5		11	12	11	
Moderate	4	4	4		2	1	2	
Severe	0	0	0		0	0	0	
Tricuspid annulus size, mm, mean ± SD	36.0 ± 7.2	38.3 ± 5.6	36.8 ± 6.8	0.25	34.6 ± 7.0	35.2 ± 6.0	35.4 ± 5.8	0.37

FUTURE :
DUAL CHAMBER
LEADLESS PM ?

CONCLUSION

- Frequent cardiac device complication
- For severe TR : poor prognosis (mortality and heart failure)
- Lack of evidence to identify patients at risk
- Difficulty in proving causal relationship lead/TR (2D TTE)
- No codified therapeutic strategy

→ Multidisciplinary approach