Tricuspid Regurgitation following Lead Extraction: Risk Factors and Clinical Course

Amir Givon MD[1]*, Natalia Vedernikova MD[1]*, David Luria MD[1,2], Ori Vatury MD[1], Rafael Kuperstein MD[1], Micha S. Feinberg MD[1], Michael Eldar MD[1,2], Michael Glikson MD[1,2] and Eyal Nof MD[1,2]

[1]Leviev Heart Center and [2]Davidai Arrhythmia Center, Sheba Medical Center, Tel Hashomer, affiliated with Sackler Faculty of Medicine, Tel Aviv University, Tel Aviv, Israel

ABSTRACT:
Background: Transvenous lead extraction can lead to tricuspid valve damage.
Objectives: To assess the incidence, risk factors and clinical outcome of tricuspid regurgitation (TR) following lead extraction.
Methods: We prospectively collected data on patients who underwent lead extraction at the Sheba Medical Center prior to laser use (i.e., before 2012). Echocardiography results before and following the procedure were used to confirm TR worsening, defined as an echocardiographic increase of at least one TR grade. Various clinical and echocardiographic parameters were analyzed as risk factors for TR. Clinical and echocardiographic follow-up was conducted to assess the clinical significance outcome of extraction-induced TR.
Results: Of 152 patients who underwent lead extraction without laser before 2012, 86 (56%) (192 electrodes) had echocardiography results before and within one week following the procedure. New or worsening TR was discovered in 13 patients (15%). Use of mechanical tools and younger age at extraction were found on multivariate analysis to be factors for TR development ($P = 0.04$ and $P = 0.03$ respectively). Average follow-up was 22.25 ± 21.34 months (range 8–93). There were no significant differences in the incidence of right-sided heart failure (50% vs. 23%, $P = 0.192$) or hospitalizations due to heart failure exacerbations (37.5% vs. 11%, $P = 0.110$). No patient required tricuspid valve repair or replacement. Death rates were similar in the TR and non-TR groups (20% vs. 33%).
Conclusions: TR following lead extraction is not uncommon but does not seem to affect survival or outcomes such as need for valve surgery. Its long-term effects remain to be determined.

IMAJ 2016; 18: 18–22

KEY WORDS: lead extraction, tricuspid regurgitation (TR), heart failure, cardiac rhythm management device (CRM)

The use of cardiac rhythm management devices (CRMs) has increased steadily in the last two decades. In the United States 245,000 devices were implanted in 2004 [1]. By 2010 nearly 500,000 were implanted annually worldwide [2]. The

---

*The first two authors contributed equally to this study

number of CRM extractions, also referred to as lead extractions, is also increasing, due to high risk implantations in the elderly with co-morbidities and to an increase in the number of CRM system upgrades. Class 1 indications for lead extraction include systemic or pocket infection, venous occlusion and life-threatening arrhythmias caused by the electrodes [3]. Multiple studies have shown pocket infection to be the major indication [2,4,5]. The preferred approach for lead extraction is intravenous rather than surgical [2,6,7], with large series demonstrating success rates exceeding 95% [6,8]. Tricuspid regurgitation (TR) following lead extraction has been described in several studies [5,9-11], with incidence rates of 3.5–12%. The theorized mechanism involves adhesions between the electrodes and tricuspid leaflets [12], causing damage to different parts of the leaflet during extraction. Known risk factors include female gender, extraction of a pacemaker rather than implantable cardioverter-defibrillator (ICD) electrodes and the use of a laser sheath [5,11]. The aim of the present study was to assess the incidence, risk factors and clinical outcome of tricuspid regurgitation following lead extraction in a single referral center in Israel.

PATIENTS AND METHODS

Prior to 2012, 152 patients underwent non-laser lead extraction at the Sheba Medical Center. Eighty-six of them met the inclusion criterion of having an echo examination both before and within one week of extraction. The study was designed as a retrospective analysis of a prospectively collected database. Data were collected and analyzed for patients who underwent lead extraction at the Sheba Medical Center between January 2004 and May 2011.

Indications for lead extraction were classified as infectious or non-infectious. Infectious indications were classified as pocket infection, bacterial endocarditis, or other systemic infection. Pocket infection was defined as erythema of the skin overlying the device with or without purulent discharge, local necrosis, or adherence of the device to the skin. Bacterial endocarditis was defined according to the modified Duke criteria; patients with sepsis who did not meet the Duke criteria but did not have a localized source of infection were categorized as having an unknown systemic infection. Non-

infectious indications were classified as venous obstruction, stenosis or dysfunctional leads.

Patients were referred for lead extraction both from within the Sheba Medical Center and from other hospitals in Israel. The procedure was performed as either elective or emergent using an intravenous approach, with patients under conscious sedation or general anesthesia.

Laser sheaths were not used during the period of the study. The tools and techniques used in sequential order were:
- Simple traction
- Simple traction plus locking stylets inserted into the lead coil for stabilization during extraction to prevent tip fracture
- Mechanical sheaths advanced over the lead to severe fibrotic adhesions
- Powered sheaths that use thermal energy to lyse adhesions
- Femoral approach if all previous methods failed.

Two echocardiograms (transthoracic), before the procedure (up to a month) and up to 7 days after the procedure, were required for inclusion. Data of a follow-up echocardiogram were obtained when available from patients who developed TR after the procedure. TR worsening was defined as an increase of at least one grade in TR between the two echocardiograms. All echocardiograms were reviewed by a single reader (O.V). TR gradient was determined by measuring the gradient along the tricuspid valve using the modified Bernoullie equation and graded as mild, moderate or severe according to the vena contracta width (defined as > 7 mm for severe) or color Doppler at the echocardiographer's discretion [13]. Data on survival were obtained from the national Ministry of Health registry. Following the initial data analysis, surviving patients were contacted for a short telephonic survey regarding their overall health as well as their implanted devices. This was confirmed by data obtained from the patient's primary care physician or cardiologist. Long-term echocardiography results were obtained when available.

STATISTICAL ANALYSIS

Continuous variables were expressed as means and standard deviations and analyzed using the Student t-test. Categorical variables were expressed as frequencies and percentages and analyzed using the chi-square test. Statistically significant values were defined as P value < 0.05. Logistic regression was used to control for age and gender.

RESULTS

Average age at extraction was 63.16 ± 18.19 years. Most patients were males (83%, n=72) who had structural heart disease (93%, n=80) and other co-morbid illnesses. Patients were implanted for an average of 7.15 ± 5.6 years before extraction.

Information on the devices and leads removed is provided in Table 1. Half (50%, n=43) of the devices removed were

Table 1. Devices and leads removed

Devices (n=86)		
	ICD, n (%)	27 (31.4%)
	PM, n (%)	43 (50%)
	CRTP, n (%)	5 (5.8%)
	CRTD, n (%)	11 (12.8%)
	Total, n (%)	86 (100%)
Leads (n=192)		
Location	Right atrium, n (%)	69 (35.9%)
	Right ventricle, n (%)	107 (55.7%)
	Left ventricle, n (%)	16 (8.3%)
	Total, n (%)	192 (100%)
Lead type	PM, n (%)	142 (73.9%)
	ICD, n (%)	49 (25.5%)
	Unknown, n (%)	1 (0.05%)
	Total, n (%)	192 (100%)
Fixation method	Active, n (%)	27 (14.1%)
	Passive, n (%)	164 (85.8%)
	Unknown, n (%)	1 (0.05%)
	Total, n (%)	192 (100%)
Right ventricle leads removed (n=107)		
	ICD, n (%)	46 (43%)
	PM, n (%)	60 (56.1%)
	Unknown, n (%)	1 (0.9%)
	Active, n (%)	11 (10.3%)

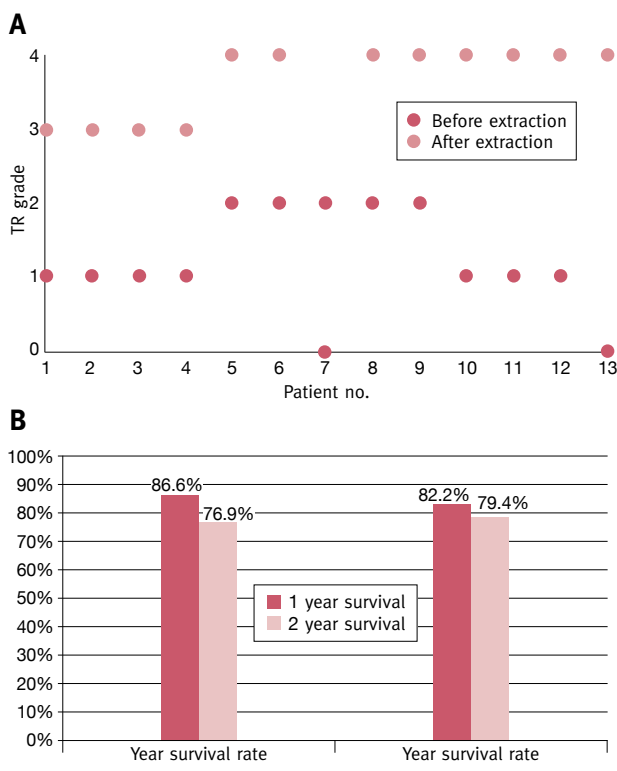ICD = implantable cardioverter defibrillator, PM = pacemaker, CRT = cardiac resynchronization therapy

permanent pacemakers (PM), 27 (31.4%) were ICDs and 16 (18.6%) were biventricular devices – 5 cardiac resynchronization therapy pacemakers (CRTP) or 11 CRT defibrillators (CRTD). Most of the 192 leads removed were PM leads (n=142, 73.9%), of which only 27 (14.1%) were active fixated leads. Detailed information on the right ventricular leads is provided in Table 1. An infection indication for removal was present in nearly all patients (94.1%, n=81).

Most leads were removed using external sheaths: 17% (15/86) with mechanical sheaths and 38% (33/86) with powered sheaths. All others were removed either with simple traction (11%, 10/86) or with the help of locking stylets (8%, 7/86). In 24% (21/86) a femoral approach was needed. This series does not include laser extractions that were introduced in our center in 2012.

An increase in the TR grade as assessed by echocardiography was detected in 13 of the 86 patients analyzed (15.1%). TR was moderate in 5 of those patients (38.4%) and severe in 8 (61.6%). In the latter severe patients, TR was mild in 4 and moderate in 4 at baseline [Figure 1A]. The mechanism of TR could be clearly demonstrated in five cases: lateral leaflet flail in one patient, eccentric posterior leaflet flail in two, an eccentric chordea tear in one and a suspected papillary muscle tear in one. No particular mechanism could be determined in the other eight patients.

Analysis of risk factors for TR worsening is provided in Table 2. The presence of atrial fibrillation at extraction was

Figure 1. TR prior and after extraction. **[A]** TR grade before and after extraction in those who developed TR. **[B]** No differences in survival rates at 1 and 2 years between patients with and without TR after extraction

Table 2. Risk factors for tricuspid regurgitation (TR) worsening

	TR worsening (n=13, 15.1%)	Control (n=73, 84.9%)	*P* value
TR grade			
Mild, n (%)	0	62 (84.9%)	‹ 0.0001
Moderate, n (%)	5 (38.4%)	7 (9.6%)	
Severe, n (%)	8 (61.6%)	4 (5.5%)	
Age, mean ± STD	52.92 ± 20.39	64.99 ± 17.29	0.027
EF, mean ± STD	38.08 ± 20.16	38.85 ± 17.42	0.889
Baseline TR ≥ 2, n (%)	3 (23.1%)	9 (12.3%)	0.55
Structural heart disease, n(%)	11 (84.6%)	69 (84.5%)	0.528
Males, n (%)	11 (84.6%)	61 (83.6%)	0.924
Lead years, mean ± STD	7.65 ± 4.34	7.07 ± 5.86	0.691
Hypertension, n (%)	2 (15.4%)	33 (45.2%)	0.044
Diabetes mellitus, n (%)	4 (30.8%)	19 (26%)	0.722
Prior CVA, n (%)	2 (15.4%)	5 (6.9%)	0.308
Atrial fibrillation, n (%)	7 (53.8%)	18 (24.7%)	0.033
Time since implant (years)	7 ± 5	7 ± 4	0.7
Right ventricle lead type			
ICD, n (%)	9 (69.3%)	34 (46.6%)	0.344
PM, n (%)	4 (30.7%)	38 (52.1%)	
Unknown, n (%)	0	1 (1.3%)	
Right ventricle lead number			
0	0	1 (1.4%)	0.461
1	9 (69.2%)	57 (78.1%)	
2	3 (23.1%)	13 (17.8%)	
3	1 (7.7%)	2 (2.7%)	
Lead fixation			
Passive	12 (92.3%)	61 (83.7%)	0.731
Active	1 (7.7%)	11 (15%)	
Unknown	0	1 (1.3%)	
Infectious indication, n (%)	13 (100%)	69 (94.5%)	0.688
Complete success, n (%)	13 (100%)	69 (94.5%)	0.688
Successful extraction method			
Simple traction/Locking stylet	0	10 (13.7%)/7 (9.6%)	0.03
Mechanical sheath	3 (23.1%)	12 (16.4%)	
Powered sheath	7 (53.8%)	26 (35.6%)	
Femoral access	3 (23.1%)	18 (24.7%)	

found to be significant on initial univariate analysis ($P = 0.033$) but non-significant following logistic regression ($P = 0.068$). The presence of arterial hypertension at extraction was found to protect against TR worsening at initial univariate analysis ($P = 0.044$) but non-significant following adjustment for age and gender ($P = 0.357$). Young age at extraction ($P = 0.023$) and use of mechanical sheaths ($P = 0.04$) were the only significant risk factors for worsening TR on multivariate analysis [Table 2]. Other factors – including electrode type (ICD vs. PM), number of electrodes removed, time since implantation, and successful extraction method – did not predict TR worsening.

Of the 86 study patients, 27 died during follow-up. Three of them were in the TR group (mortality rate 20%) and 24 were control subjects (mortality rate 32.9%). First-year survival rate was 84% (11/13) in the TR group and 82% (60/73) in the non-TR group. Second-year survival rate was 77% (10/13) in the TR group and 79% (58/73) in the non-TR group. There was no significant difference in the mortality rate ($P = 0.746$) [Figure 1B]. Five patients died within 30 days of the extraction, one in the TR group and 4 in the control group; the cause of death was severe sepsis and multi-organ failure in all five cases.

Follow-up results are summarized in Table 3. Despite a trend in favor of the non-TR group, there were no statistically

Table 3. Patient follow-up

Follow-up available/ surviving patients	TR 8/10 (80%)	Control 43/49 (87.8%)	*P* value
Follow-up duration in months, mean ± STD	22.25 ± 21.34	38.68 ± 25.86	0.09
Carrying pacemakers	6 (75%)	36 (83.7%)	0.619
NYHA class III-IV	4 (50%)	27 (62.8%)	0.456
Right HF symptoms	4 (50%)	10 (23.3%)	0.192
Hospital admissions, 1 year	3 (37.5%)	5 (11.6%)	0.099
Additional extraction	0	2 (4.7%)	1
Tricuspid valve repair	0	0	1

significant differences in rates of congestive heart failure symptoms, right heart failure symptoms or number of hospitalizations between both groups since the procedure. Two patients underwent a second lead extraction following the initial procedure; none of the patients underwent tricuspid valve repair or replacement.

Of the 10 TR patients who survived, echocardiographic long-term follow-up data were available for 5. All five showed progression in right ventricular dilatation and in three there was progression of TR. None of these patients were hospitalized for heart failure or developed right-sided heart failure symptoms.

DISCUSSION

TR worsening following lead extraction has been described in several studies over the last decade; however, its clinical implications are not fully understood. Our study aimed to identify risk factors for TR worsening and determine its effects regarding patient survival and quality of life.

Our study population was similar to those of previous studies regarding age, cardiac function and co-morbid illnesses. The almost exclusive indication for lead extraction was infectious (n=81, 94.1%), most commonly pocket infection (n=44, 51.2%), in accordance with previous studies. Most extractions required the use of a sheath, either mechanical or powered (n=48, 55.8% for both methods). A smaller proportion were successfully completed using only simple traction (n=10, 11.6%) and locking stylets (n=7, 8.2%). Notably, our series did not include patients who underwent transvenous laser lead-assisted extraction.

The incidence of TR worsening following lead extraction in our study was 15.1% (n=13), higher than previously reported rates; however, TR following lead extraction was defined differently in each of those studies. In our study the primary endpoint was TR worsening, defined as an increase of at least one TR grade following lead extraction. Franceschi et al. [5] studied traumatic TR, defined as TR with a demonstration of flail leaflet only on echocardiogram, and Glover and co-authors [11] defined TR in their study as moderate or severe TR (grades II-III) with a baseline grade of mild (grade I) or no TR.

We identified two factors that predicted TR worsening. One was use of mechanical sheaths, and the other was young age at extraction. A possible explanation for younger age as a risk factor could be a diminished fibrotic reaction to the foreign body insertion among elderly patients and thus a less traumatic extraction. It has been shown that older age is a risk factor for delayed wound healing and scar formation due to a depressed inflammatory response and decreased proliferation of fibroblasts and epithelial cells [14]. Other factors were initially found to be risk factors (atrial fibrillation) or protecting factors (hypertension), but were found to be non-significant after adjustment for age and gender. Interestingly, type of lead, age of lead, number of leads or even time since implantation were not found to predict TR.

Follow-up time (mean 36 ± 25.72 months, range 7–91, median 29) was similar to previous studies. Most patients (n=40, 81.6%) were re-implanted at follow-up.

In our study TR was not found to be associated with mortality. None of our patients needed tricuspid valve surgery. TR worsening was also not found to be a predicting factor for adverse effects such as depressed New York Heart Association functional class, right heart failure, or increased number of hospitalizations. These findings contrast with previous studies which observed cases of severe TR following lead extraction with heart failure necessitating tricuspid valve repair. TR was shown to be an independent risk factor for mortality in patients with congestive heart failure [15], who comprise a large proportion of the study population. We have previously shown that TR worsening following CRTP or CRTD implantation predicted decreased clinical and echocardiographic response to the treatment [16]. However, in the absence of pulmonary hypertension, TR is usually asymptomatic. In fact, tricuspid bacterial endocarditis is often treated with tricuspid valvectomy without re-implantation for months or even years [17]. This might be the reason for the relatively benign effect of TR on our patient population.

LIMITATIONS

Our study has several limitations. The first was its relatively small number of patients which might lead to lack of statistical power in identifying other TR predictors. The second was the incomplete follow-up in all patients. Many of the patients who underwent extraction at the Sheba Medical Center returned immediately to treatment in their original CRM clinic and were thus lost to follow-up. Another limitation is the lack of data on laser extraction. However, a significant number of institutions still do not use the laser-powered sheath for extractions at all or at least regularly, and thus we believe a study like ours is relevant. Furthermore, the natural history of TR following extraction remains relevant regardless of the extraction tool used. The third limitation is that some of the basic echocardiograms were performed in other institutions. In contrast, all post-extraction echocardiograms were done in our institution and were reviewed by a single reader (O.V.). We do not believe this would have affected the conclusions of this study since this occurred only in a minority of the pre-extraction echocardiograms. We hold that differences between mild and moderate or moderate and severe TR can be reliably accounted for in most cases even with various echocardiogram interpreters.

CONCLUSIONS

TR after extraction did not affect survival, worsen heart failure or result in corrective surgery. The only predictors for TR development following extraction were use of mechanical sheaths and relatively young age at the time of extraction.

Correspondence

Dr. E. Nof
Leviev Heart Center, Sheba Medical Center, Tel Hashomer 52621, Israel
Phone: (972-3) 530-2608, 530-5330
Fax: (972-3) 530-5804, 535-6605
email: eyal.nof@sheba.health.gov.il

References

1. Zhan C, Baine WB, Sedrakyan A, Steiner C. Cardiac device implantation in the United States from 1997 through 2004: a population-based analysis. *J Gen Intern Med* 2008; 23 (Suppl 1): 13-19.

2. Farooqi FM, Talsania S, Hamid S, Rinaldi CA. Extraction of cardiac rhythm devices: indications, techniques and outcomes for the removal of pacemaker and defibrillator leads. *Int J Clin Pract* 2010; 64: 1140-7.

3. Cleland JG, Daubert JC, Erdmann E, et al. The effect of cardiac resynchronization on morbidity and mortality in heart failure. *N Engl J Med* 2005; 352: 1539-49.

4. Wazni O, Epstein LM, Carrillo RG, et al. Lead extraction in the contemporary setting: the LExICon study: an observational retrospective study of consecutive laser lead extractions. *J Am Coll Cardiol* 2010; 55: 579-86.

5. Franceschi F, Thuny F, Giorgi R, et al. Incidence, risk factors, and outcome of traumatic tricuspid regurgitation after percutaneous ventricular lead removal. *J Am Coll Cardiol* 2009; 53: 2168-74.

6. Smith MC, Love CJ. Extraction of transvenous pacing and ICD leads. *Pacing Clin Electrophysiol* 2008; 31: 736-52.

7. Wilkoff BL, Love CJ, Byrd CL, et al. Transvenous lead extraction: Heart Rhythm Society expert consensus on facilities, training, indications, and patient management: this document was endorsed by the American Heart Association (AHA). *Heart Rhythm* 2009; 6: 1085-104.

8. Bongiorni MG, Soldati E, Zucchelli G, et al. Transvenous removal of pacing and implantable cardiac defibrillating leads using single sheath mechanical dilatation and multiple venous approaches: high success rate and safety in more than 2000 leads. *Eur Heart J* 2008; 29: 2886-93.

9. Assayag P, Thuaire C, Benamer H, Sebbah J, Leport C, Brochet E. Partial rupture of the tricuspid valve after extraction of permanent pacemaker leads: detection by transesophageal echocardiography. *Pacing Clin Electrophysiol* 1999; 22: 971-4.

10. Roeffel S, Bracke F, Meijer A, et al. Transesophageal echocardiographic evaluation of tricuspid valve regurgitation during pacemaker and implantable cardioverter defibrillator lead extraction. *Pacing Clin Electrophysiol* 2002; 25: 1583-6.

11. Glover BM, Watkins S, Mariani JA, et al. Prevalence of tricuspid regurgitation and pericardial effusions following pacemaker and defibrillator lead extraction. *Int J Cardiol* 2010; 145: 593-4.

12. Novak M, Dvorak P, Kamaryt P, Slana B, Lipoldova J. Autopsy and clinical context in deceased patients with implanted pacemakers and defibrillators: intracardiac findings near their leads and electrodes. *Europace* 2009; 11: 1510-16.

13. Zoghbi WA, Enriquez-Sarano M, Foster E, et al. Recommendations for evaluation of the severity of native valvular regurgitation with two-dimensional and Doppler echocardiography. *J Am Soc Echocardiogr* 2003; 16: 777-802.

14. Hwang JS, Chang I, Kim S. Age-associated decrease in proteasome content and activities in human dermal fibroblasts: restoration of normal level of proteasome subunits reduces aging markers in fibroblasts from elderly persons. *J Gerontol A Biol Sci Med Sci* 2007; 62: 490-9.

15. Koelling TM, Aaronson KD, Cody RJ, Bach DS, Armstrong WF. Prognostic significance of mitral regurgitation and tricuspid regurgitation in patients with left ventricular systolic dysfunction. *Am Heart J* 2002; 144: 524-9.

16. Abu Sham'a R, Buber J, Grupper A, et al. Effects of tricuspid valve regurgitation on clinical and echocardiographic outcome in patients with cardiac resynchronization therapy. *Europace* 2012; 15: 266-72.

17. Zipes D, Libby P, Bonow R, Braunwald E. Braunwald's Heart Disease, a Textbook of Cardiovascular Medicine. 7th edn. Philadelphia: Elsevier Publishing, 2005: chapter 57, p. 1603-6.

"You have not converted a man because you have silenced him"

John Morley (1838-1923), British statesman, writer and newspaper editor