Aortic Regurgitation and Left Ventricular Remodeling After Transcatheter Aortic Valve Implantation
A Serial Cardiac Magnetic Resonance Imaging Study

Constance Merten, MD; Hans-Wilko Beurich, MD; Dirk Zachow, MD; Ahmad E. Mostafa, MD; Volker Geist, MD; Ralph Toelg, MD; Gert Richardt, MD; Mohamed Abdel-Wahab, MD

**Background**—Aortic regurgitation (AR) after transcatheter aortic valve implantation (TAVI) has been associated with poor outcomes, but little is known about how it evolves over time. We evaluated left ventricular (LV) function, remodeling, and the occurrence and evolution of AR after TAVI by using cardiac MRI.

**Methods and Results**—Forty-three patients treated with transfemoral TAVI underwent cardiac MRI 1 week and 6 months after TAVI. LV volumes and function were assessed by using standard cine MRI sequences. Phase-contrast imaging was performed to quantify the degree of AR. The mean age of the evaluated patients was 80 years, and 65% of patients were women. At baseline MRI, the median LV ejection fraction was 58.1%, which improved significantly at follow-up to 63.4% (P<0.0001). A significant reduction of LV end-diastolic volume (149.7±41.4–140.1±43.9 mL; P=0.014) and of LV mass (156.3±32.8–142.7±39.3 g; P<0.001) was observed. Over time, aortic regurgitant fraction increased slightly but significantly from 5.2% to 7.8% (P=0.04). Subgroup analysis revealed that significant changes of LV ejection fraction, volumes, and mass only occurred in patients with no or mild AR at baseline MRI, whereas those parameters remained unchanged in patients with AR more than or equal to grade II.

**Conclusions**—By using cardiac MRI in patients with TAVI, a significant improvement of LV function, volume, and mass can be documented. Mild-to-moderate AR is commonly seen, and AR shows a small increase over time. More-than-mild AR seems to prevent LV functional and structural recovery after TAVI. (Circ Cardiovasc Interv. 2013;6:476-483.)

**Key Words:** aortic valve insufficiency ■ cardiac MRI ■ TAVI ■ ventricular function, left

Transcatheter aortic valve implantation (TAVI) has recently emerged as an effective alternative therapy for patients with severe symptomatic aortic stenosis considered to be at high or prohibitive surgical risk. Mild paravalvular aortic regurgitation (AR) is frequent after TAVI with an incidence ranging from 40% to 94% probably because of the presence of the calcified native valve between the prosthesis and the aortic annulus preventing complete sealing of the paravalvular space. More-than-mild AR has been recently associated with an increased early and late mortality. Little is known about how AR after TAVI evolves over time. In addition, limited data are available about the impact of TAVI on LV volumes, function, and mass, and whether residual AR influences change in LV structure and function.

Cardiac MRI is the gold standard method for the assessment of LV function and can be combined with flow measurements over the aortic valve or prosthesis for the evaluation of AR. Compared with the evaluation of AR by echocardiography, MRI is more sensitive in patients with paravalvular, eccentric, or multiple jets like those frequently observed after TAVI. We therefore sought to evaluate LV function, LV remodeling, and the occurrence and evolution of AR in the early and medium-term follow-up after TAVI by using serial cardiac MRI.

**Methods**

**Patient Population**

Between October 2008 and January 2012, all patients treated with TAVI at our institution were screened for inclusion into this prospective study (n=170; Figure 1). Indication for TAVI was in concordance with the recent consensus statement. Data collection was approved by the Institutional Review Board, and all patients signed an informed written consent. Patients with a contraindication to MRI (eg, pre- or post-TAVI pacemakers or MRI incompatible implants) and patients with claustrophobia, severe arrhythmias, or unstable clinical conditions were excluded from the study. Ultimately, a total of 55 consecutive patients treated with TAVI with the use of the 2 currently commercially available bioprostheses (Medtronic CoreValve,

**Correspondence to** Mohamed Abdel-Wahab, MD, Herzzentrum, Segeberger Kliniken GmbH, Am Kurpark 1, 23795 Bad Seengeberg, Germany. E-mail mohamed.abdel-wahab@segebergerkliniken.de

**The online-only Data Supplement is available at** http://circinterventions.ahajournals.org/lookup/suppl/doi:10.1161/CIRCINTERVENTIONS.112.000115/-/DC1.

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WHAT IS KNOWN

- Paravalvular aortic regurgitation after transcatheter aortic valve implantation has been associated with poor outcomes, but little is known about how it evolves over time, and on its potential impact on left ventricular remodeling.
- The assessment of aortic regurgitation after transcatheter aortic valve implantation by using echocardiography is complex and challenging.

WHAT THE STUDY ADDS

- By using cardiac MRI, significant positive left ventricular remodeling occurs within 6 months after transcatheter aortic valve implantation.
- Aortic regurgitation quantified by MRI does not decrease over time.
- In patients with more-than-mild AR, no positive left ventricular remodeling is observed.

Medtronic Inc, Minneapolis, MN and Edwards Lifesciences, Irvine, CA were included. Of these 55 patients, 43 patients with TAVI were included in the final analysis. The remaining 12 patients underwent baseline MRI examinations, but follow-up MRI scans could not be performed because of the following: death during the follow-up period (n=1), pacemaker implantation during the follow-up period (n=1), refusal of follow-up MRI (n=6), aborted follow-up MRI attributable to claustrophobia (n=2), and loss to follow-up (n=2; Figure 1). All patients who refused to undergo follow-up MRI were in good clinical condition and therefore refused the follow-up MRI attributable to claustrophobia (n=2), and loss to follow-up (n=1), refusal of follow-up MRI (n=6), aborted follow-up MRI (n=2). The baseline MRI scan was performed 1 to 2 weeks after TAVI, the follow-up MRI 6 months later. Cardiac MRI was performed by using a clinical 1.5 Tesla whole-body scanner (Magnetom Espree, Siemens AG, Erlangen, Germany). All patients were investigated by ECG-gated cardiac MRI in the supine position with a 5-element cardiac phased-array coil. The stent carrying the Medtronic CoreValve prosthesis is made up of nitinol, which is not ferromagnetic and can therefore be safely examined by MRI (Figure 2). The stent frame of Edwards valve is composed of cobalt chrome material; nonclinical testing revealed that it can be safely scanned under routine MRI conditions. LV volumes and function were determined by cine images using a standard steady-state free precession sequence in continuous short-axis planes covering the whole left ventricle from base to apex. For flow measurements, a breath-hold velocity-encoded phase-contrast MR sequence was used (through plane, segmented fast low-angle shot 2-dimensional sequence, repetition time/echo time 46/2.7 ms, velocity encoding 150–300 cm·s−1, scan in expiration, scan duration 10 s). The slice was positioned perpendicular to the long axis of the ascending aorta closely beneath the upper margin of the stent holding the CoreValve prosthesis or at the corresponding distance from the aortic annulus for the Edwards valve, respectively. This position was chosen because it had proved to be less susceptible to artifacts caused by the valves and stent compared with a lower position, and a perpendicular cut through the ascending aorta could be achieved more accurately. In fact, no visible artifacts of valves and stents were present on the analyzed images. Contrast administration was not necessary for both cine imaging and flow measurements. Consequently, no patients were excluded because of impaired renal function.

MRI Protocol

The baseline MRI scan was performed 1 to 2 weeks after TAVI, the follow-up MRI 6 months later. Cardiac MRI was performed by using a clinical 1.5 Tesla whole-body scanner (Magnetom Espree, Siemens AG, Erlangen, Germany). All patients were investigated by ECG-gated cardiac MRI in the supine position with a 5-element cardiac phased-array coil. The stent carrying the Medtronic CoreValve prosthesis is made up of nitinol, which is not ferromagnetic and can therefore be safely examined by MRI (Figure 2). The stent frame of Edwards valve is composed of cobalt chrome material; nonclinical testing revealed that it can be safely scanned under routine MRI conditions. LV volumes and function were determined by cine images using a standard steady-state free precession sequence in continuous short-axis planes covering the whole left ventricle from base to apex. For flow measurements, a breath-hold velocity-encoded phase-contrast MR sequence was used (through plane, segmented fast low-angle shot 2-dimensional sequence, repetition time/echo time 46/2.7 ms, velocity encoding 150–300 cm·s−1, scan in expiration, scan duration 10 s). The slice was positioned perpendicular to the long axis of the ascending aorta closely beneath the upper margin of the stent holding the CoreValve prosthesis or at the corresponding distance from the aortic annulus for the Edwards valve, respectively. This position was chosen because it had proved to be less susceptible to artifacts caused by the valves and stent compared with a lower position, and a perpendicular cut through the ascending aorta could be achieved more accurately. In fact, no visible artifacts of valves and stents were present on the analyzed images. Contrast administration was not necessary for both cine imaging and flow measurements. Consequently, no patients were excluded because of impaired renal function.

170 pts. underwent TAVI between 10/08 and 01/12

- 33 pts. had PPM/ICD before TAVI
- 30 pts. had PM implanted after TAVI
- 4 pts. were switched to SAVR
- 16 pts. died before completing the study protocol
- 15 pts. with prolonged ICU stay, stroke, other neurologic disorders, dementia or poor general condition
- 4 pts. with contraindication for MRI
- 13 pts. refused to undergo MRI

55 pts. underwent baseline MRI

- 1 pt. died shortly before the follow-up MRI
- 1 pt. received a PM after the first MRI
- 2 pts. aborted MRI due to claustrophobia
- 6 pts. refused to undergo follow-up MRI
- 2 pts. were lost to follow-up

43 patients with baseline and follow-up MRI included into the final analysis.

Figure 1. Study population. A detailed description of the study population as part of the overall transcatheter aortic valve implantation (TAVI) cohort treated during the study period. ICU indicates intensive care unit; PM, pacemaker; and SAVR, surgical aortic valve replacement.
MRI data were analyzed by 2 independent and experienced observers. No formal blinding was performed, but observers had no access to the results of the baseline scan at the moment of evaluation of follow-up MRI. Global LV function was assessed by manually contouring the endocardial borders of end-diastolic and end-systolic images. For the computation of LV mass, the epicardial borders were additionally contoured at end diastole. LV volumes, mass, and ejection fraction were then automatically calculated by the software (Argus WIP 2.3, Siemens AG, Erlangen, Germany). An LV ejection fraction (LVEF) >55% was considered normal.

For the assessment of the aortic regurgitant fraction (RF), the cross-sectional area of the ascending aorta was defined and manually corrected for motion artifacts that occurred during the breath-hold scan. By using the standard software (see above), the forward and reverse volumes within this region of interest were determined, and the RF was calculated (Figure 3). An RF of ≤15% was graded I (mild), 16% to 30% was graded II (moderate), 31% to 50% was graded III (moderate to severe), and >50% was graded IV (severe) AR according to the standard grading criteria.13,21 A calculated RF<1% was classified as no AR (grade 0).

**Natriuretic Peptides Assay**

Blood samples were drawn preprocedurally, at baseline MRI and the MRI follow-up visit. N-terminal pro-brain natriuretic peptide (NT-proBNP) was analyzed by using a commercially available kit (The Elesys proBNP, Roche Diagnostics, Mannheim, Germany).

**Statistical Analysis**

For statistical analysis, MedCalc version 10.3.0 (MedCalc Software, Mariakerke, Belgium) was used. Descriptive results are expressed as numbers and percentages, and continuous variables are expressed as mean±SD or median and range. For comparison of initial and follow-up MRI parameters, paired Student t test or Wilcoxon signed-rank test was used, based on the distribution of the change in value. Additionally, Pearson correlation coefficients were calculated to evaluate the relation of LV parameters and aortic regurgitation. A P value <0.05 was deemed significant.

**Results**

**Baseline Characteristics**

Overall patient characteristics are summarized in Table 1. The mean age of the study patients was 79.9±5.5 years, and 65% of patients were women. Baseline New York Heart Association (NYHA) functional class was IV in 5 patients and III in 33 patients, and 5 patients had NYHA class II symptoms at baseline. The median logistic European System for Cardiac Operative Risk Evaluation (EuroSCORE) was 17% (range, 7%–82%). Thirty-five patients had a concomitant diagnosis of coronary artery disease; in 13 patients, a percutaneous coronary intervention was performed within 1 week before TAVI. Thirty-two patients (74%) were treated with the Medtronic CoreValve prosthesis, and 11 patients received the Edwards Sapien XT valve.
The mean transvalvular pressure gradient decreased from 48.2±16.7 mm Hg before intervention to 9.1±4.7 mm Hg after TAVI (P<0.0001). Angiographic assessment of AR was performed immediately after the procedure. No AR was seen in 13 (30%) of the 43 patients. AR was mild (grade I) in 24 patients (56%), whereas in 6 patients (14%), a moderate AR (grade II) was observed.

Baseline MRI was performed at a median of 11 days after TAVI. At baseline examination, any AR (RF>1%) was present in 37 of the 43 patients (86%); in 6 patients (14%), no AR was observed. While mild AR was present in 29 patients (68%), moderate AR was observed in 7 patients (16%) and, in 1 patient (2%), moderate-to-severe AR was detected. The median RF of the entire cohort was 5.18% (range, 0.11%–38.9%). The mean heart rate during flow measurements was 64.1±11.3 bpm.

Baseline MRI showed a median LVEF of 58.1% (range, 22.1%–71.6%). A normal ejection fraction was seen in 23 patients, and another 10 patients had only slightly reduced systolic LV function with an LVEF of 50% to 55%; in 10 patients, the LVEF was more severely impaired. The mean end-diastolic volume (EDV) was 149.7±41.4 mL, the median end-systolic volume was 63.4 mL (range, 22.8–203.0 mL). Early after TAVI, the mean myocardial mass was 156.3±32.8 g.

Follow-up MRI
Follow-up MRI was performed at a median of 6 months after TAVI (range, 5–12 months). AR of any grade was present in 39 of the 43 patients (91%). We observed grade I AR in 31 patients (72%), grade II AR in 5 patients (12%), and grade III AR in 3 patients (7%; Figure 4). Over time, the median-calculated aortic RF increased slightly but significantly from 5.2% to 7.8% (P=0.04; Table 2; Figure 4). The mean heart rate during flow measurement at follow-up did not differ from baseline MRI (64.1±11.3 versus 64.0±11.7 bpm; P=0.94).

On the contrary, we observed a significant increase of the median LVEF at follow-up MRI (58.1% versus 63.4%; P<0.0001). There was also a significant decrease of the EDV (149.7±41.4 versus 140.1±43.9 mL; P=0.014) and of the LV myocardial mass (156.3±32.8 versus 142.7±39.3 g; P<0.001; Table 2; Figure 5). The increase of LVEF was not affected by pre-TAVI revascularization with percutaneous coronary intervention.

Impact of AR on LV Recovery
No significant correlation was observed between RF and LV ejection fraction at baseline MRI (r=0.28), whereas a modest, but significant, correlation was seen between RF and LVEF at follow-up MRI (r=-0.37; P=0.017). There was no significant correlation between the RF at baseline and changes in LVEF (r=-0.18; P=0.24), but we observed a strong trend toward a correlation between baseline RF and changes in LV mass (r=0.30; P=0.053), and a significant correlation between RF at baseline and changes in EDV (r=0.40; P=0.008; Figure I in the online-only Data Supplement). Subgroup analysis revealed that significant changes of LVEF, EDV, and LV mass only occurred in patients with

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**Table 1. Baseline Patient Characteristics Before TAVI**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>79.9±5.5</td>
</tr>
<tr>
<td>Females (%)</td>
<td>28/43 (65)</td>
</tr>
<tr>
<td>Diabetes mellitus (%)</td>
<td>11/43 (26)</td>
</tr>
<tr>
<td>Hypertension (%)</td>
<td>37/43 (86)</td>
</tr>
<tr>
<td>Hyperlipidemia (%)</td>
<td>28/43 (65)</td>
</tr>
<tr>
<td>Obesity (%)</td>
<td>6/43 (14)</td>
</tr>
<tr>
<td>BMI, kg/m²</td>
<td>26.0 (17.3–57.2)</td>
</tr>
<tr>
<td>Logistic EuroSCORE (%)</td>
<td>16.6 (7.8–82.0)</td>
</tr>
<tr>
<td>NT-proBNP, pg/mL</td>
<td>2842 (201–49344)</td>
</tr>
<tr>
<td>NYHA class II (%)</td>
<td>5/43 (12)</td>
</tr>
<tr>
<td>NYHA class III (%)</td>
<td>33/43 (77)</td>
</tr>
<tr>
<td>NYHA class IV (%)</td>
<td>5/43 (12)</td>
</tr>
<tr>
<td>Coronary artery disease (%)</td>
<td>35/43 (81)</td>
</tr>
<tr>
<td>PCI during admission (%)</td>
<td>13/43 (30)</td>
</tr>
<tr>
<td>Previous PCI (%)</td>
<td>16/43 (37)</td>
</tr>
<tr>
<td>Previous CABG (%)</td>
<td>9/43 (21)</td>
</tr>
<tr>
<td>Previous myocardial infarction (%)</td>
<td>8/43 (19)</td>
</tr>
</tbody>
</table>

Data presented as mean±SD, median and range, or number and percentage. Obesity defined as BMI>30 kg/m². BMI indicates body mass index; CABG, coronary artery bypass graft; EuroSCORE, European System for Cardiac Operative Risk Evaluation; NT-proBNP, N-terminal pro-brain natriuretic peptide; NYHA, New York Heart Association; PCI, percutaneous coronary intervention; and TAVI, transcatheter aortic valve implantation.

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**Prosthetic Valve Function After TAVI**

The mean transvalvular pressure gradient decreased from 48.2±16.7 mm Hg before intervention to 9.1±4.7 mm Hg after TAVI (P<0.0001). Angiographic assessment of AR was performed immediately after the procedure. No AR was seen in 13 (30%) of the 43 patients. AR was mild (grade I) in 24 patients (56%), whereas in 6 patients (14%), a moderate AR (grade II) was observed.

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no or mild AR at baseline MRI, whereas those parameters remained unchanged in patients with AR more than or equal to grade II (Table 3).

**Plasma Concentrations of NT-proBNP**

Preinterventionally, NT-proBNP levels were considerably elevated with a median value of 2842 pg/mL (range, 201–49 344 pg/mL). In the early postinterventional period, we observed a significant reduction of NT-proBNP levels (2842 versus 2019 pg/mL; \( P =0.025 \)). During a longer follow-up period, we found a further decrease of NT-proBNP serum levels compared with pre-TA VI levels (2842 versus 1336 pg/mL; \( P =0.0001 \)) as well as a significant reduction between baseline and follow-up MRI (2019 versus 1336 pg/mL; \( P =0.017 \)). Additionally, a moderate, but significant, correlation between the RF and NT-proBNP levels was observed at baseline (\( r =0.33; \ P =0.046 \)) and at follow-up (\( r =0.32; \ P =0.045 \); Figure II in the online-only Data Supplement).

**Discussion**

In recent years, TAVI has emerged as an alternative treatment to surgical aortic valve replacement for patients with severe symptomatic aortic stenosis and high or prohibitive surgical risk. Clinical short- and medium-term outcomes compare favorably with the outcome of surgical aortic valve replacement.1,2,12 Yet, most published series observed a high incidence of paravalvular AR after TAVI, which occurs in up to 94% of patients3–8 and is at least moderate in up to one fifth of them. The present study is the first to use cardiac MRI for the evaluation of the incidence and evolution of AR after TAVI and its impact on LV functional and structural recovery.

By using cardiac MRI, we found AR of any grade in 86% of patients early after TA VI, and moderate or severe AR in 19%, which is concordant with previous studies. Similar to the surgical experience,22 postprocedural AR after TA VI has been recently associated with increased short- and intermediate-term mortality.8,12 Nevertheless, the few follow-up data available suggested a stable course or even a decrease in the incidence and severity of AR after TAVI.6,10,23 In contrast, we observed a small increase in the incidence and severity of paravalvular AR at follow-up, with any grade of AR present in most examined patients.

There are several possible reasons for this discrepancy. First, in previous studies, patients were examined by using echocardiography. Compared with TTE, MRI has a lower intraobserver and interobserver variability in the assessment of regurgitant volumes and might therefore be more reliable for serial measurements.24 In addition, we demonstrated in a previous study that conventional TTE has its limitations in detecting and quantifying post-TAVI AR compared with MRI.17 The limitations of TTE have been recently highlighted in the European Association of Echocardiography/American Society of Echocardiography recommendations for the use of

![Figure 5. Left ventricular (LV) function and aortic regurgitant fraction at baseline and follow-up MRI.](http://circinterventions.ahajournals.org/)

**Table 2. Cardiac MRI and NT-proBNP Measurements Shortly After TAVI and at Follow-up**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Baseline MRI</th>
<th>Follow-up MRI</th>
<th>Sample Change</th>
<th>( P ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV ejection fraction, %</td>
<td>58.1 (22.1 to 71.6)</td>
<td>63.4 (24.0 to 74.2)</td>
<td>4.88 (−6.3 to 18.7)</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>LV EDV, mL</td>
<td>149.7±41.4</td>
<td>140.1±43.9</td>
<td>−9.6±24.5</td>
<td>0.014</td>
</tr>
<tr>
<td>LV mass, g</td>
<td>156.3±32.8</td>
<td>142.7±39.3</td>
<td>−13.6±21.2</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Aortic RF, %</td>
<td>5.2 (0.1 to 38.9)</td>
<td>7.8 (0.0 to 41.9)</td>
<td>1.3 (−7.8 to 14.7)</td>
<td>0.04</td>
</tr>
<tr>
<td>NT-proBNP, pg/mL</td>
<td>2019 (328 to 23 529)</td>
<td>1336 (312 to 30 764)</td>
<td>−579 (−8 373 to 7235)</td>
<td>0.025</td>
</tr>
</tbody>
</table>

Data presented as mean±SD or median and range. \( P \) value obtained by using either the paired Student t test or the Wilcoxon signed-rank test according to the distribution of the change in value. EDV indicates end-diastolic volume; LV, left ventricular; NT-proBNP, N-terminal pro-brain natriuretic peptide; RF, regurgitant fraction; and TAVI, transcatheter aortic valve implantation.
echocardiography in transcatheter valve interventions.25 TTE allows only semiquantitative estimation, and eccentric or multiple jets are possibly underestimated. In contrast, by using flow measurements by cardiac MRI, a quantitative assessment of AR is possible, which is independent of the number or eccentricity of the regurgitant jets.17 Another possible explanation for the increasing AR might be a higher compliance of the left ventricle attributable to the dwindling of LV mass after TAVI. This could also explain why this increase of AR was not observed after shorter periods of follow-up. A recently published study using standardized core echocardiography laboratory analysis revealed similar findings with a small, but significant, increase in AR during a 3-year observation period.26 However, on an individual basis, AR was stable in most patients with changes of only a few percentage of RF. Because of the grading of AR according to the absolute RF, very small changes of RF could nevertheless result in a different AR grade between baseline and follow-up MRI. The clinical value of these minor however statistically significant changes remains to be determined.

Previously published data analyzing changes in LV systolic function after TAVI are conflicting. Several studies found unchanged LVEF during follow-up of up to 1 year after TAVI,27,28 whereas in others, a highly significant increase of LV ejection fraction after TA VI are conflicting. Several studies revealed inconsistent results on this topic with a reduction of LV diameters29,30 in some publications, whereas in others, no significant changes were found.27,28 Interestingly, this reduction of EDV could be observed despite a significant increase of AR in the entire cohort. This might be attributable to a statistical rather than a physiological effect because there was no decrease in EDV in the subgroup of patients with AR more than or equal to grade II; in the larger group of patients with AR less than or equal to grade I, however, the decrease was significant. This is also underscored by the significant correlation we observed between aortic RF and changes in EDV between baseline and follow-up MRI and the correlation between RF and NT-proBNP levels, both reflecting an increased volume overload associated with higher baseline RF. The lack of significant change in LV volumes in these patients may signal an important effect on LV structure during the long term; however, larger studies are needed to assess whether this would negatively impact the changes observed in LV function.

Finally, our finding of a significant reduction of LV mass is in line with the results of previous echocardiography studies that gave homogeneous evidence of LV mass regression after TAVI.23,27–29 The rapid LV mass regression that is generally observed after TAVI, and much less after surgical aortic valve replacement, may be partly explained by the fact that both TAVI prostheses correspond to stentless surgical valves and have larger valve areas and lower transvalvular gradients.29 Previous work demonstrated the association of LV fibrosis in patients with severe aortic stenosis and functional recovery after surgical aortic valve replacement.30 In the elderly population receiving TAVI, a higher degree of myocardial fibrosis might be assumed, so that the findings of early improvement of systolic LV function and mass regression are even more interesting. But again, these positive changes were not observed in patients with more-than-mild AR.

### Study Limitations

There are several limitations to our study. First, we could not obtain follow-up data for all initially examined patients, and only 20% of those examined showed more-than-mild AR. Therefore, the exact influence of significant AR after TAVI on temporal changes of LV function, volumes, and mass cannot be determined because the study population was too small for robust subgroup analyses. Second, because the presence of cardiac devices such as pacemakers is a contraindication for cardiac MRI, all patients with such devices had to be excluded from the study. This lowered the number of eligible patients because atriointerimetric valve or bundle–branch block is a common complication of TAVI. Additionally, only clinically stable patients participated in this MRI study, so that patients with severe AR or severely impaired LV function might have been excluded. The slightly different hemodynamics of the CoreValve prosthesis compared with the Edwards Sapien XT valve might impact AR and functional recovery. However, because of the small number of patients receiving the Edwards valve (n=11), no subgroup analysis was performed to compare both prostheses.

### Conclusions

By using cardiac MRI in patients with TAVI, a significant improvement of LV function, volume, and mass can be documented 6 months after valve implantation. Mild-to-moderate AR is commonly seen after TAVI, and AR shows a small increase over time. More-than-mild AR seems to prevent LV functional and structural recovery after TAVI.

### Acknowledgments

We thank Dr Derek R. Robinson (senior lecturer of statistics, University of Sussex, Brighton, England) for his professional statistical support. We are grateful to Dr Judith Hummerjohann and Kathrin

### Table 3. Changes in LV Function and Structure Stratified by the Degree of Post-TAVI Aortic Regurgitation

<table>
<thead>
<tr>
<th>AR grade 0 or I (n=35)</th>
<th>Follow-up MRI</th>
<th>Sample Change</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVEF, %</td>
<td>57.0±9.4</td>
<td>62.3±7.9</td>
<td>5.3±5.7</td>
</tr>
<tr>
<td>EDV, mL</td>
<td>141.2±32.8</td>
<td>128.3±29.0</td>
<td>−12.9±18.8</td>
</tr>
<tr>
<td>LV mass, g</td>
<td>150.8±31.6</td>
<td>135.0±33.4</td>
<td>−15.8±14.8</td>
</tr>
</tbody>
</table>

AR indicates aortic regurgitation; EDV, end-diastolic volume; EF, ejection fraction; LV, left ventricular; and TAVI, transcatheter aortic valve implantation.

Data presented as mean±SD. P value obtained by using the paired Student t test.
Disclosures

Drs Richardt and Abdel-Wahab report receiving a research grant from Medtronic. The other authors report no conflict.

References


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Aortic Regurgitation and Left Ventricular Remodeling After Transcatheter Aortic Valve Implantation: A Serial Cardiac Magnetic Resonance Imaging Study
Constanze Merten, Hans-Wilko Beurich, Dirk Zachow, Ahmad E. Mostafa, Volker Geist, Ralph Toelg, Gert Richardt and Mohamed Abdel-Wahab

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SUPPLEMENTAL MATERIAL

Supplemental table

Baseline demographics and cardiac MRI measurements of the study cohort compared to patients who only underwent baseline MRI

<table>
<thead>
<tr>
<th></th>
<th>Study cohort (n=43)</th>
<th>Baseline MRI only (n=12)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>79.9 ± 5.5</td>
<td>83.7 ± 5.3</td>
<td>0.04</td>
</tr>
<tr>
<td>Females (%)</td>
<td>28/43 (65)</td>
<td>8/12 (67)</td>
<td>0.60</td>
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<tr>
<td>Logistic EuroSCORE (%)</td>
<td>16.6 (7.8 – 82.0)</td>
<td>22.3 (11.4 – 54.4)</td>
<td>0.12</td>
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<tr>
<td>LV ejection fraction (%)</td>
<td>58.1 (22.1 – 71.6)</td>
<td>53.0 (32.1 – 65.8)</td>
<td>0.35</td>
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<tr>
<td>LV EDV (ml)</td>
<td>149.7 ± 41.9</td>
<td>146.4 ± 39.6</td>
<td>0.80</td>
</tr>
<tr>
<td>LV mass (g)</td>
<td>156.3 ± 32.8</td>
<td>133.5 ± 16.7</td>
<td>0.02</td>
</tr>
<tr>
<td>Aortic RF (%)</td>
<td>5.2 (0.1 – 38.9)</td>
<td>5.5 (1.0 – 13.3)</td>
<td>0.53</td>
</tr>
</tbody>
</table>

Data presented as mean ± SD, median and range, or number and percent

MRI = magnetic resonance imaging; LV = left ventricular; EDV = enddiastolic volume; RF = regurgitant fraction
Supplemental figures and figure legends

Supplemental figure 1: Correlation between regurgitant fraction at baseline MRI and changes in enddiastolic volume.

EDV = enddiastolic volume, RF1 = regurgitant fraction at baseline MRI
Supplemental figure 2: Correlation between regurgitant fraction and NT-proBNP levels at baseline and follow-up MRI

RF 1 = regurgitant fraction at baseline MRI; RF 2 = regurgitant fraction at follow-up MRI