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| **Pulmonalklappenprothesen** | |
| Lokalisation | The native pulmonary valve is located anterior and superior to the aortic valve and is best visualized with TTE using the RVOT view from the parasternal window (modified from the parasternal shortaxis view at the aortic valve level) or subcostal window. |
| Lage Prothese | The prosthetic valve is not always in the same position as the native pulmonary valve, especially when a conduit is involved. |
| Off-Axis | It is important to understand that off-axis views may be necessary when using echocardiography. |
| CT und MRT | CT and CMR provide improved spatial resolution and should be used to complement the echocardiographic findings. |
| RVOT, PA, RV, Druck | When assessing the pulmonary valve prosthesis, additional information on anatomy of the RVOT and PA as well as RV size, function, and pressures are important to include. |
| Mit oder ohne Conduit | The native diseased pulmonary valve may be replaced either by a valved conduit for complete repair of a congenital defect or by a prosthetic valve without a conduit in isolated valve pathology. |
| Fallot, Rastelli, Ross, Yasui | The most common indication for a valved conduit is tetralogy of Fallot. Other indications include the Rastelli procedure (transposition of the great arteries with ventricular septal defect) or as part of a Ross procedure (congenital aortic valve stenosis) or Yasui repair (interrupted aortic arch with diminutive ascending aorta). |
| Conduit biologisch | The valved conduit is generally a biologic tissue (e.g., homograft, xenograft). |
| Gestentete biologische Prothesen | Stented biologic prostheses are generally implanted for pulmonary valve regurgitation, which most commonly occurs in patients who have previously undergone RVOT reconstruction.156 |
| Transkatheter-PVR | Transcatheter PVR was first reported in 2000 and has since become a viable alternative to surgical PVR in select patients.157 |
| Vergleich PVR | Outcomes for both types of interventions are favorable and comparable, with transcatheter PVR associated with shorter hospital stays and periprocedural complications but higher rates of endocarditis.158 |
| Zunahme PVR | The number of PVR procedures has increased over the years, with a consistently increasing trend in surgical PVR.159 |
| PVR bei jüngeren Patienten | Additionally, the age at PVR is markedly heterogeneous among centers across the United States, with administrative data indicating an overall increase in younger patients receiving a PVR over time.160 |
|  | Trends suggest that more absolute numbers of adult patients are likely to present for evaluation of pathologic complications of replaced prostheses. |
| Typen | It is important to understand the types of surgical and transcatheter replacements to better understand the risk for complications. |
| Ort der Flussbeschleinigung | Echocardiographic and Doppler evaluation: When characterizing the severity of prosthetic stenosis, it is important to remember that high flow velocities may be encountered in locations other than the prosthetic valve. |
| Gefäßaststenosen | Branch vessel stenosis or conduit edge stenosis may also be present and confound CW Doppler interrogation of velocities across the prosthetic valve. |
| Schwierigkeiten | Previous ASE guidelines have described the general imaging considerations and challenges of evaluating PVR, including the unconventional shape of the RVOT, the location of the prosthesis, and association with surgically placed conduits.1 |
| Echo-Evaluation: Typ, Größe, Hinweise für Obstruktion, Thrombus, Pannus, Quantitativ, Verlauf | Echocardiographic assessment of valve obstruction should include (1) characterization of the type and size of prosthesis as noted in Table 14, (2) observation of qualitative indicators of obstruction (e.g., thrombus, pannus), (3) quantitation of severity of stenosis, and (4) any changes from previous assessments in serial examinations. |
| RV-Druck | In addition, RV systolic pressure should be determined using the jet of TR, if present. |
| sPAP = sRV-Druck-sPVG | Of note, PA systolic pressure in the presence of PVR stenosis is the difference between RV systolic pressure and the gradient across the obstructed valve. |
| Biologisch | Biologic prostheses remain the most common type of PVR. |
| Kurze Wirksamkeit | However, these valves are likely to eventually fail and require replacement. |
| Mechanisch nur selten | Mechanical prostheses are infrequently implanted in this position, thus data on pathology affecting these valves is sparse. |
| Mehr PVR, mehr Stenosen | Given that a younger age at PVR is prognostic of prosthetic valve failure and that more PVR procedures are being performed in younger individuals, prosthetic pulmonary valve stenosis will become more common.161 |
| Stenose > Insuffizienz | Prosthetic valve failure or dysfunction predominantly manifests as stenosis rather than regurgitation, with an approximately 80% incidence within 10 years of initial implantation.161 |
| Bei Endokarditis mehr Prothesenstenosen | When endocarditis occurs in PVR or conduits, obstruction at the time of diagnosis is more common than severe regurgitation: 53% vs 29%, respectively.162 |
| Stenoseort | Identifying the location of stenosis is important, as the obstruction may occur further along a conduit or in the PA rather than at the valve. |
| PW-Doppler um den genauen Ort rauszufinden | PW Doppler is helpful in determining the precise location of obstruction. |
| Indirreke Stenosezeichen: Conduitverschmählerung, RV-Hypertrophie | Narrowing of the conduit and impact on the right ventricle are also indicators of an obstructive lesion. |
| Vmax MPG | Quantitative parameters are generally limited to peak velocity and mean gradient (Figure 23). |
| Mechanische Klappen haben geringeren Geradient als biologische | Interestingly, there are data to suggest that normally functioning mechanical prostheses are more likely to have lower peak velocity and mean gradient compared with biologic valves in the pulmonary position.163 |
| Hinweise für Stenose: Gradient 15, vmax 2,5, Turbulenz, TAPSE, RV-Hypertrophie, RV-Druck, RV Dil, DVI vermindert (RVOT/PV) | Indicators of prosthetic stenosis are provided in Table 15. |
| TEE schwierig, da PV anterior | TEE can be challenging when evaluating a PVR, as the pulmonary valve is an anterior structure and if there is a conduit, the location is atypical. |
| RV-inflow outflow ME oder TG | Classically, TEE of the pulmonary valve is in the midesophageal view with the transducer angle at 50 to 70 or from the deep transgastric view with transducer angle approximately 50 to 90. 164 |
| Bester Winkel: langsam von 0-90 Grad in Farbdoppler | It is helpful to use color Doppler to locate the prosthesis and to pan from 0 to 90 to find the best angle, especially in congenital heart disease (CHD). |
| PW und CW | PW and CW Doppler are important to evaluate for valve or conduit stenosis. |
| 3D bei 60 Grad | Live 3D or 3D zoom using the midesophageal view with the transducer angle at 50 to 70 can be used to display the en face view of the pulmonary valve from the PA side or the RVOT side with rotation to display the anterior leaflet at the 12 o’clock position.26 |
| Multiplan rekonstruktion | Multiplane reconstruction of the 3D data set can quickly be used to evaluate the commissures of the three leaflets for calcification or fusion in addition to tracing the valve orifice.165 |
| ICE | For percutaneous pulmonary valve reimplantation, ICE provides better visualization of the homograft or conduit and may identify infective endocarditis associated with the prosthetic valve.166,167 |
| MRT CINE | Cine imaging with SSFP or gradient echo allows visualization of the pulmonary prosthesis, the right ventricle, and the PA with its bifurcation. |
| MRT Bacl bood | Black blood imaging or gated turbo (fast) spin-echo can be used if there is stent artifact and allows assessment of the vessel, as it has decreased sensitivity to metal artifacts, with the limitation of being a static image.168 |
|  | Through-plane phase-contrast imaging through the prosthesis allows assessment of the peak velocity through the valve, conduit, and/or the main PA or PAs separately. |
|  | If there is a stent artifact, phase contrast can be placed just proximal and distal to the stent artifact.169 |
| Geschwindigkeit im MRT geringer | The peak velocity generally is slightly lower than that obtained by Doppler echocardiography at an optimal angle. |
| Kontrast-Angio MRT | Contrast-enhanced magnetic resonance angiography obtains a 3D data set that can be used to further identify the areas of stenosis. |
| Late Gadolinium für Thrombus | Late gadolinium enhancement with long T1 times can be used to identify thrombus as a cause of stenosis.127,170 |
| MRT nicht für Kalk | CMR cannot be used to accurately assess calcification of the prosthesis or conduit. |
| Bei Stent-Artefakt CT besser als MRT | When significant stent-related artifact prevents adequate assessment on CMR, CT can be used to evaluate the pulmonary valve or conduit (Figure 24).171 |
| CT bei unklarer Ätiologie | This can be helpful whenthe etiology of stenosis is not clear or for evaluation for percutaneous structural intervention. |
|  | Electrocardiographically gated contrast-enhanced whole–cardiac cycle imaging is recommended, particularly where percutaneous intervention is required. |
| Calk kann nicht für Graduierung verwendet werden | The presence of calcification is indicative of structural valvular degeneration but cannot be used for quantitation of the degree of stenosis. |
| CT für Pannus oder Thrombus | The presence of cusp thickening, pannus, or thrombus can also be assessed for other causes of stenosis.172 |
| CT für Diameter | Cardiac CT may be used to determine the size of the valve or conduit using the effective diameter derived from area or perimeter measurement if previous surgical notes are not available. |
| CT Diameter bei Conduits nicht genau | However it should be noted that these measurements are less accurate in conduits, where postoperative calcification can lead to alterations in size and shape.17 |
| PR in Prothesen: wenig Daten | There is a paucity of data specifically evaluating PR in prosthetic valves; therefore, the information available is extrapolated from assessment of PR in native valves. |
| PR: Dehiszens CW-Dichte, Jetbreite am Annulus, PHT, PW; RVOT/PW LVOT erhöht; RV-Dilatation; Flussumkehr in PA | Table 16 details the echocardiographic findings in various degrees of prosthetic PR severity, and Table 17 shows the pros and cons of each imaging modality in assessing PR. |
| Deg, Veg, Quantifizierung, Prothesenart, Verlauf | Echocardiographic assessment of PR should include (1) characterization of the type and size of prosthesis; (2) the presence of relevant anatomic abnormalities, such as degeneration or vegetations; (3) quantitation of severity of regurgitation; and (4) any changes from previous assessments in serial examinations. |
| RV, IVS in Diastole | Additionally, assessment of the RV size and interventricular septal position and motion during diastole is needed. |
| Stenose > Insuffizienz | As discussed previously, prosthetic pulmonary stenosis occurs more frequently than regurgitation in both degeneration and endocarditis |
| Conduit: Stenose und Regu | However, when a valved conduit is present, both stenosis of the conduit and regurgitation of the valve can occur (Figure 23). |
| Farbe, CW, PW | Color, PW, and CW Doppler are used to assist with the evaluation (Table 16). |
| Farbdoppler: Jetdauer, Jetbreite | Color Doppler demonstrates diastolic flow into the RVOT, and jet duration and jet width assist in determining the severity. |
| Hochgradig = geringe Jetdauer! | Severe PR has a short jet duration, as the PA and RV diastolic pressures equalize quickly, making it challenging to visually appreciate the PR. |
| Farbjet über 50% des Annulus | A color jet width >50% of the prosthesis annulus suggests severe PR. |
| Cave exzentrische Jets und Paravalvular regurgitaion | These parameters are less reliable in eccentric and paravalvular regurgitation. |
| Flussumkehr in PA spricht zumidest für mittelgradig | Reversal of flow in the distal main PA by PW Doppler is suggestive of at least moderate PR. |
| Deceleration ist von Compliane des RV abhängig | A brief diastolic deceleration time is also suggestive of severe PR, but this is also dependent on the compliance of the right ventricle. |
| 4,9 m/sec2 | In a study comparing CMR with echocardiography, a PHT 4.9 m/sec2 indicated a need for pulmonary valve intervention.174 |
| Wenige Methodden auf Prothesen anwendbar bei PR | There are limited methods for quantification of PR that can be extrapolated to prosthetic valves. |
| Ggf. Regurgitationsvolumen bestimm | A comparison of stroke volume obtained just below the PVR and stroke volume obtained at the aortic or mitral valve can provide a measurement of regurgitant volume and fraction (in the absence of AR or MR, respectively). |
| RF 50% | A regurgitant fraction 50% is considered severe.1 |
| TEE | The use of TEE described previously in the section on pulmonary stenosis can help evaluate the severity of PR (Table 17).3 |
| TEE Calk und Thromben | Prosthetic valves can have calcification and thrombus, which are better visualized using TEE. |
| GGF 3D | The evaluation of PR using 3D TEE can also be achieved with live 3D, 3D zoom, or multiplanar reconstruction. |
| 3D Klapppe in Draufsicht | The added value of 3D TEE is to see the valve en face with the regurgitant orifice.26 |
| ICE | ICE may be a consideration in evaluating a PVR when TEE is inconclusive.166,167 |
| CT Segel Moblität Prolaps | Although CT can be used to detect leaflet mobility and the presence of prolapse, its temporal resolution is limited. |
| Anatomische Regurgitationsöffnung fragl. | Furthermore, although the anatomic regurgitant orifice area has been demonstrated as a useful tool for the quantification of AR, no studies are available for PR. |
| CT Lokalisation von OVL | However, CT may be useful for the precise localization and sizing of PVLs.78 |
| Phasenkontrat-Imiganging im MRT bei Regurgitaton | The benefit of CMR for assessment of regurgitation is quantification using phase-contrast imaging (Figure 24).169 |
| CMR bessr als Echo für PR | CMR is superior to echocardiography for quantification of PR.168 |
| RF < 35% dann mild | On the basis of measured regurgitant fraction, the severity of PR is mild when 35%.175 |
| RF > 40% dann hochgradig | Other investigators consider a regurgitant fraction >40% as severe.176 |
| Phasenkontradt auch bei multiplen Jets und exzenrischen Jets | Phase-contrast CMR is not affected by multiple or eccentric jets. |
| Ebene kann außerhalb des Artefakts platziert werdden | The through plane can be placed outside of the valvular artifact if need. |
| 4D Flow | Newer sequences such as 4D flow can be used to better understand the direction of the flow and quantitate the regurgitation, however its reliability has not been proven at this time. |
| MRT für RV-Volumen | Additionally, quantification of RV volumes is important in the assessment of PR and is best evaluated using CMR |

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