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Clinical Application of Echocardiography in Treatment of One Case of Mechanical Aortic Valve Stenosis with Giant Ventricular Aneurysm

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AUTHOR CONTRIBUTIONS
Qiu-Ying Liu: Drafting the manuscript.
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HUMAN AND ANIMAL RIGHTS
This case report does not involve.

CONSENT
We obtained written informed consent from the patient for submission of this manuscript for publication.

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ABSTRACT

This paper reports a middle-aged woman who underwent mechanical aortic valve replacement surgery for congenital aortic valve malformation 7 years ago, and she had presented with exertional dyspnea and frequent ventricular arrhythmias in recent years. Transthoracic echocardiography revealed severe stenosis of the mechanical aortic valve orifice, as well as showed changes in left ventricular morphology caused by increased left ventricular afterload, which mainly manifested as localized hypertrophy of interventricular septum and a giant apical aneurysm. We used Simpson's biplane method to pre-estimate the volume of left ventricular basal cavity, and assisted surgeons to make surgical plan in preliminarily.

During the operation, we assessed the shape, volume, and systolic function of left ventricular after left ventricular plasty, and determined that there were no potential risk factors for left ventricular outflow tract obstruction by transesophageal echocardiography. Under the guidance of transthoracic echocardiography, surgeons did not perform myocardial resection but performed mitral valve replacement. Finally, the patient was discharged smoothly.

CASE REPORT

CASE REPORT

The patient was a 42-years-old female, who presented to our hospital due to chest tightness and shortness of breath after exertion, intermittent arrhythmia for more than 2 years. She accidentally discovered a small ventricular aneurysm during an echocardiogram check-up 17 years ago, and underwent a mechanical aortic valve replacement for congenital aortic stenosis 7 years ago. She was implanted an Implantable Cardioverter Defibrillator (ICD) due to suffering frequent premature ventricular contractions 2 years ago, and later experienced intermittent ICD discharge. Therefore, she underwent radiofrequency ablation 3 months ago, but recurred in a short time.

On examination, the patient was vitally stable and had the following characteristics of vital signs: body mass index, 19.53 kg/m^2; body surface area (BSA), 1.59m^2; respiratory rate, 19 times/min; blood pressure (BP), 97/64mmHg; heart rate, 78bpm; NYHA grade III. There was a surgical scar of 23cm in front of her sternum, enlargement of the cardiac border. The mechanical aortic valve opening and closing sound was clear. There was a grade 2 diastolic rumbling murmur in the mitral valve (MV) auscultation area.

There was no significant stenosis in both the left and right coronary according to arteries coronary angiography, with thrombolysis in myocardial infarction (TIMI) grade were 3. The dynamic electrocardiogram showed that the patient had sinus rhythm and pacemaker rhythm(working in VVI mode), paroxysmal ventricular tachycardia, multi-source premature ventricular contractions, 5063 beats per 24 hours, and complete right bundle branch block.

Transthoracic echocardiography (TTE) showed the following features: the left ventricular cavity morphology had changed, appearing like a gourd. The apical myocardium became thin and bulged outward, measuring 5× 4cm, which exercised paradoxically. Multiple strands but no thrombus were visible in the apical aneurysm. The thickness of middle interventricular septum (IVS) was 18mm, and the thickness of other walls were 9mm, which contracted normally. The diameter of left ventricular outflow tract (LVOT) was 26mm, and the flow velocity was 85cm/s, pressure gradient (PG) was 3mmHg. There was no systolic anterior motion (SAM), mitral regurgitation (MR) was mild. There were no vegetations on the surface of the mechanical aortic valve, its annulus diameter was only 17mm, and the diameter of aortic sinus, sinotubular junction, ascending aorta were normal. The peak flow velocity of the prosthetic valves was 380cm/s, the peak pressure gradient (PPG) was 53mmHg, the mean pressure gradient (MPG) was 28mmHg, and the effective orifice area (EOA) was 1.0cm^2, the effective orifice area index (EOAI) was 0.62 cm^2/m^2 that calculated by the continuity equation. We measured the left ventricular end-diastolic volume (LV-EDV) was131 mL, left ventricular end-systolic volume (LV-ESV) was 98 mL, left ventricular stroke volume (LV-SV) was 33 mL, left ventricular ejection fraction (LV-EF) was 25% by Simpson's biplane method. In order to assess the degree of stenosis of prosthetic valves under stress condition, the patient underwent squatting test which was a simple provocation test. After squatting test, the peak flow velocity of the mechanical aortic valve increased to 440cm/s, PPG increased to 74mmHg, MPG increased to 41mmHg, and MR increased to moderate. TTE preliminary diagnosed that severe prosthetic-patients mismatch (PPM) of the mechanical aortic valve orifice, a giant apical aneurysm, hypertrophy of the middle IVS, secondary MR, and left ventricular systolic function reduced significantly (Figures 1,2).

We performed a secondary thoracotomy surgery for her, including secondary replacement of mechanical aortic valve, enlargement of aortic valve annulus, resection of apical aneurysm, left ventricular radiofrequency ablation, with preparation for resection of IVS and MV replacement. On operation, there was an apical aneurysm, measuring 4×6 cm. Therefore, we resected the apical aneurysm, performed an apical plasty, and performed cryoablation of the anterior and posterior papillary muscle roots under direct visualization. We incised the aorta and peeled off the original mechanical aortic valve, which had no vegetations on its surface. Then we enlarged the aortic valve annulus and replaced the valve with a Medtronic 505DA20 mechanical valve (EOA, 1.7cm^2; EOAI, 1.05cm^2/m^2 in this case). We observed the structure and hemodynamic changes of the heart by transesophageal echocardiography (TEE) after cardiopulmonary bypass was removed, while the patient's heart resumed sinus rhythm at 40 bpm and BP 90/50mmHg. We detected that the new mechanical aortic valve was opening well with MPG was 9mmHg, wihtout regurgitation and perivalvular leakage. LVOT-PG was 5mmHg, and the left ventricular cavity morphology was in good shape, appearing like a cone, and all ventricular walls exercising actively. But MR increased to severe degree (Figures 3,4), so we restarted the bypass machine and replaced MVwith Medtronic 26 mechanical valve. Finally, the surgery was completed successfully.

TTE showed that the left ventricular cavity morphology had returned to normal conical shape, LV-EDV was 89mL, LV-SV was 48mL, LV-EF was 54%, the MPG of the new mechanical aortic valve was 21mmHg, EOA was1.4cm^2, EOAI was 0.88cm^2/m^2, and LVOT-PG was 6 mmHg before discharge.

DISCUSSION

We described a case of severe stenosis of mechanical aortic valve orifice with left ventricle aneurysm. Its complications lied in the significant differences in the systolic function of different segments of the left ventricle, i.e. the basal myocardial movement was active, the apical movement was absent and the apical aneurysm movement was paradoxical. As a result, hemodynamic changes were complex and mutually influential. So, we had taken the following aspects into account when making the surgical decision.

Mechanical aortic valve stenosis

Before aortic valve replacement, the surgeon normally choose an appropriate model based on the size of the annulus measured by multi-slice spiral Computed Tomography (CT) and ultrasound. Effective valve area index is preliminarily calculated according to the prosthetic valve model and EOA comparison table provided by the manufacturer, combined with the BSA. But postoperative prosthetic valve stenosis remains a common complication because of calcification, pannus, thrombosis, and prosthetic-patient mismatch (PPM) [1, 2]. It has been reported that the prevalence of moderate PPM after aortic valve replacement is 20% to 70%, and the prevalence of severe PPM ranges from 2% to 20% [3]. Diagnosis of prosthetic valve stenosis is not easy, especially for mechanical valves, because the valve is made of metal and cannot be scanned for Magnetic Resonance Imaging (MRI) after surgery, and CT scans cannot show the structure of the valve due to metal artifacts. Alternatively, the diagnosis of mechanical valve stenosis mainly relies on Doppler ultrasound to estimate EOAI from the continuity equation, which is key to diagnosing and quantifying prosthetic valve stenosis [4]. At present, most Chinese doctors applied the evaluation recommendations given in the 2016 report

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of the European Cardiovascular Imaging Association, that is, the peak velocity > 400cm/s, MPG> 35 mmHg, and EOA < 0.80 cm^2 suggest severe aortic stenosis and EOAI ≤0.65cm 2 /m2, suggest severe PPM [5]. In this case, prosthetic valve stenosis was severe because the annular diameter measured by TTE was only 17 mm, EOA was 1.0 cm^2EOAI was 0.62 cm^2/m^2, but no neoplasm were detected according to the degree of PPM recommended by the literature [5]. And what we saw during the operation confirmed our diagnosis. As a result, the surgeon widened the aortic annulus and replaced a larger prosthetic valve in the secondary operation. 505DA20 mechanical aortic valve with EOA is 1.7 cm^2 , it was enough for this patient and was effective in preventing the recurrence of PPM [6].

Ventricular aneurysm

Ventricular aneurysms are mostly acquired and often secondary to myocardial infarction, rarely secondary to apical hypertrophic cardiomyopathy and dilated cardiomyopathy. This may be related to mid-chamber obstruction, anterior descending coronary artery myocardial bridge, myocardial thickening, etc [7,8]. In this case, the patient's coronary angiography showed no stenosis of the coronary arteries. Therefore, we could rule out the possibility of ventricular aneurysm caused by coronary stenosis. Rarely, ventricular aneurysms are congenital and tend to occur in the apex and free wall, and the wall is made up of reticular fibrous tissue that causes ventricular tachycardia or ventricular arrhythmias [9,10]. The clinical manifestations and general observations during the operation in this case suggested that the ventricular aneurysm was congenital. If we cut off the aneurysm completely, which occupied more than half of the volume of the left ventricular cavity, the volume of the left ventricular cavity would be greatly reduced. To assess whether left ventricular volume could be preserved adequately or not after operation, we traced the endocardium of the left ventricular cavity except for the part of aneurysm, and predicted the volume of the remaining left ventricular cavity after removal of the ventricular aneurysm by TTE Simpson's biplan method before surgery. The results showed that the residual LV-EDV was 85 mL, LV-ESV was 36 mL, LV-SV was 49 mL, and LV-EF was 58%. Therefore, we boldly predict that the residual stroke volume in this case would be able to meet the physiological needs of the woman after removal of the whole ventricular aneurysm. In order to ensure the safety and long-term effectiveness of the procedure, TEE was used to reconfirm the left ventricular volume and systolic function during the operation, the results showed that the residual LV-EDV was 88 mL, LV-ESV was 42 mL, LV-SV was 46 mL, and LV-EF was 52% (Table 1).

Suicide left ventricle

In this patient, her compensatory thickening of the middle IVS was18 mm, the volume of left ventricle would decrease significantly after aneurysm resection, and once the artificial aortic stenosis was relieved, the pressure in left ventricular cavity would drop sharply. In this situation, anterior mitral valve would be attracted to build up dynamic left ventricular outflow tract obstruction (LVOTO). This is called suicide left ventricle [11]. Therefore, we also prepared a generic plan to remove the hypertrophic myocardium. During the operation, TEE detected no sign of SAM and LVOT-PG was 5 mmHg when the heart regained sinus rhythm with 40 bpm and BP was 90/50 mmHg after secondary valve replacement and ventricular aneurysm resection. Till then, could we rule out LVOTO, and the hypertrophic myocardium was not resected.

Mitral valve regurgitation

The function of MV depends on a balance between normal left ventricular wall contraction and traction to maintain the structural integrity of the MV. In this case, the MR in the preoperative resting state was mild, which was secondary to left ventricular systolic dysfunction. The level of regurgitation increased to moderate after squatting test. The reason for the increase in regurgitation is that the myocardium contracts excessively in order to adapt to the increased oxygen consumption of the myocardium, but at the same time, the myocardial traction on the valve leaflets also increases excessively [12]. After the ventricular aneurysm was resected, TEE showed a significant increase in MR. We considered that the original middle of the left ventricle became the reshaped apex after left ventricle was reshaped, the papillary muscle was now attached to apex, which was equivalent to downward movement of the papillary muscle. Excessive stretching of the valve by the systolic papillary muscles resulted in increased MR. So we opened cardiopulmonary bypass again, and performed MV replacement decisively.

TEACHING POINTS

Echocardiography plays an important role before, during, and after secondary surgery patients with multiple heart diseases. It can visually show the morphology of the lesion and analyze the mechanism of lesion, especially, it has the advantages that cannot be replaced by other imaging examinations in observing the dynamic change process of lesions in real time. It plays a guiding role in the formulation and modification of surgical protocols.

QUESTIONS

Question 1: What are the potential risk factors for left ventricular suicide after secondary valve replacement and ventricular aneurysm resection in this case?

A. Compensatory thickening of the middle IVS.

B. The volume of left ventricle would decrease significantly after aneurysm resection.

C. The pressure in left ventricular cavity would drop sharply once the artificial aortic stenosis was relieved.

D. Alteration of the position of the subvalvular structures of the mitral valve after left ventricloplasty.

E. All of the above. (applies)

Answer 1: All of the above. (In this patient, her compensatory thickening of the middle IVS was18 mm, the volume of left ventricle would decrease significantly after aneurysm resection,

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and once the artificial aortic stenosis was relieved, the pressure in left ventricular cavity would drop sharply. In this situation, anterior mitral valve would be attracted to build up dynamic left ventricular outflow tract obstruction (LVOTO). This is called suicide left ventricle.)

Question 2: What is the diversity of the left ventricular myocardium in this patient?

A. The thickness is different: the basal segment is normal, the middle segment is thickened, and the apical segment is thinned.

B. Systolic function is different: normal contraction of the basal segment, excessive contraction of the middle segment and paradoxical movement of the apical segment.

C. Morphological abnormalities: the basal segment is basically normal, the middle segment is concave inward, and the apical segment bulges outward.

D. The thickness of left ventricular walls were normal except IVS.

E. All of the above. (applies)

Answer 2: All of the above. (the left ventricular cavity morphology had changed, appearing like a gourd. The apical myocardium became thin and bulged outward, measuring 5× 4cm, which exercised paradoxically. The thickness of middle interventricular septum (IVS) was 18mm, and the thickness of other walls were 9mm, which contracted normally.)

Question 3: During this operation, due to the aggravation of mitral valve regurgitation, we opened cardiopulmonary bypass for the second time for mitral valve replacement, so what is the reason for the aggravation of regurgitation?

A. The papillary muscle is displaced downward after aneurysm resection.

B. Long-term deformation of the left ventricular cavity leads to mitral valve tissue redundancy.

C. Left ventricular myocardial contractility is altered.

D. Left ventricular walls contracted incongruously.

E. All of the above. (applies)

Answer 3: All of the above. (After the ventricular aneurysm was resected, TEE showed a significant increase in MR. We considered that the original middle of the left ventricle became the reshaped apex after left ventricle was reshaped, the papillary muscle was now attached to apex, which was equivalent to downward movement of the papillary muscle. Excessive stretching of the valve by the systolic papillary muscles resulted in increased MR.)

Question 4: What are the evaluation recommendations for severe aortic stenosis ?

A. the peak velocity > 400cm/s.(applies)

B. MPG> 35 mmHg.(applies)

C. EOA < 0.80 cm^2.(applies)

D. EOAI < 1. 0cm^2/m^2.

E. PPG> 30 mmHg.

Answer 4: The peak velocity > 400cm/s, MPG> 35mmHg, EOA < 0.80 cm^2. (At present, most Chinese doctors applied the evaluation recommendations given in the 2016 report of the European Cardiovascular Imaging Association, that is, the peak velocity > 400cm/s, MPG> 35 mmHg, and EOA < 0.80 cm^2 suggest severe aortic stenosis.)

Question 5: What are criterias of severe prosthesis-patient mismatch in this case ?

A. The annular diameter was 17 mm.

B. EOA was 1.0 cm^2.

C. EOAI was 0.62 cm^2/m^2.

D. There were no vegetations on the surface of the mechanical aortic valve.

F. All of the above. (applies)

Answer 5: All of the above. (In this case, prosthetic valve stenosis was severe because the annular diameter measured by TTE was only 17 mm, EOA was 1.0 cm^2EOAI was 0.62 cm^2/m^2, but no neoplasm were detected according to the degree of PPM recommended by the literature.)

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FIGURES

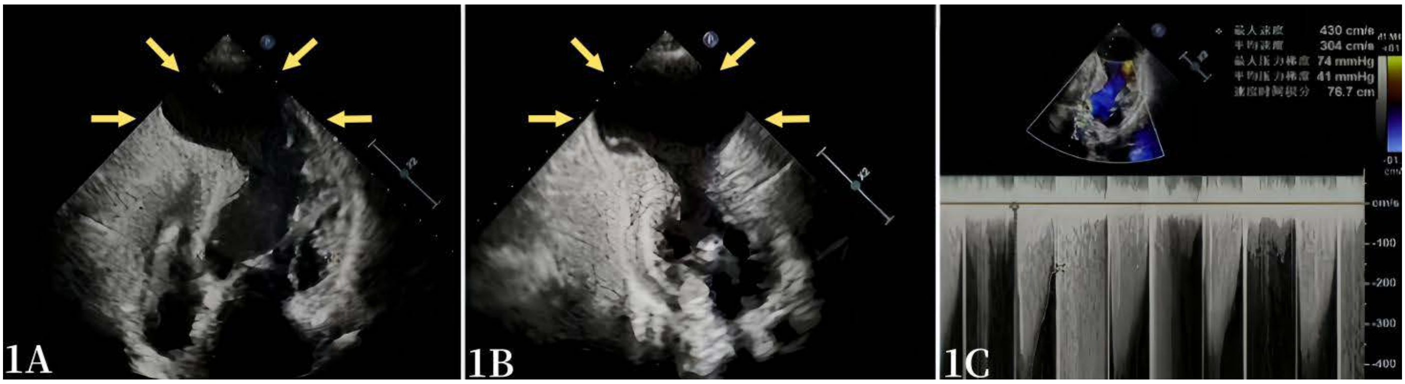

Figure 1: Preoperative transthoracic echocardiogram. 1A shows a large apical aneurysm in four-chamber view; 1B shows the left ventricular cavity in two-chamber view appearing like a gourd; 1C shows the high-speed flow spectrum of the mechanical aortic valve orifice after squatting.

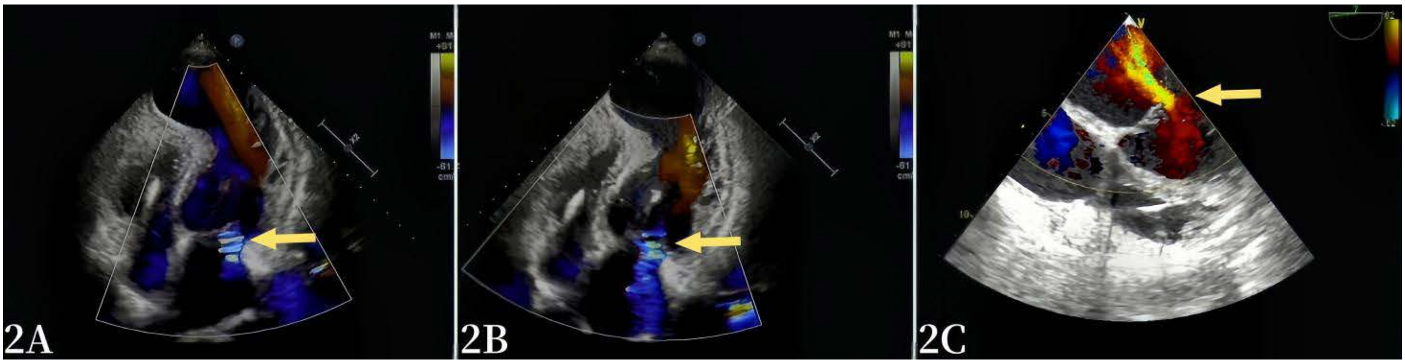

Figure 2: Changes in mitral regurgitation volume. 2A depicts mild MR on a transthoracic four-chamber view in resting state before operation; 2B shows an increase to moderate MR on a transthoracic four-chamber view after squatting test before operation; 2C illustrates severe MR on a transesophageal mid-esophageal four-chamber view after the heart has restarted following the resection of the ventricular aneurysm and secondary aortic valve replacement.

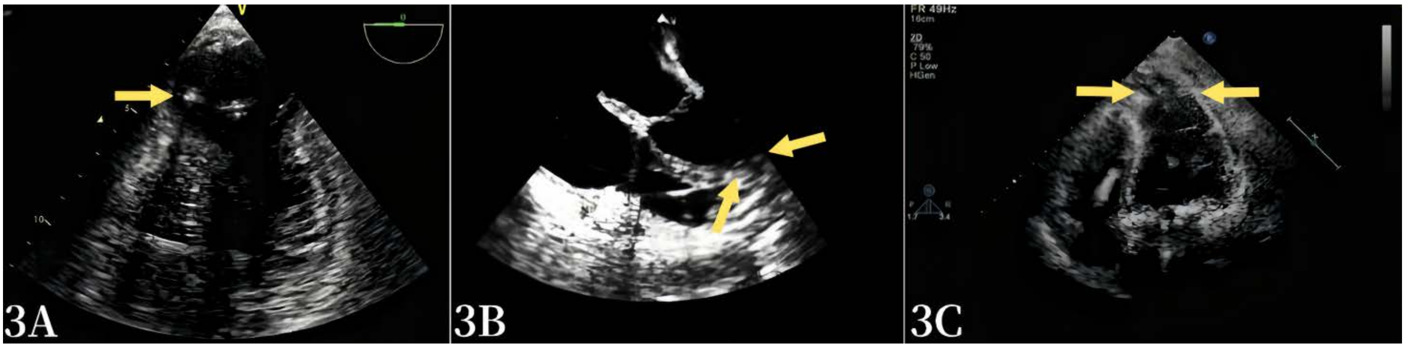

Figure 3: Left ventricular cavity morphology. 3A shows a large protrusion at the apex of the heart after induction of anesthesia via TEE at the transgastric four-chamber view, with visible strands inside; 3B shows the restoration of the left ventricular cavity to a conical shape after the resection of the ventricular aneurysm, with LV-EDV was 88mL, LV-EF was 52%; 3C shows the left ventricular cavity morphology approximating a conical shape before discharge via TTE, with LV-EDV was 89mL, LV-EF was 54%.

Figure 4: Intraoperative gross findings. 4A shows a giant ventricular aneurysm with many strands; 4B shows the original artificial mechanical aortic valve with a smooth surface and no vegetations.

Table 1: Simpson's biplane method for measuring left ventricular volume and systolic function.

Measurement Phase	LV-EDV	LV-ESV	LV-SV	LV-EF
Preoperative TTE	131 mL	98 mL	33 mL	25%
Predicted TTE	85 mL	36 mL	49 mL	58%
Intraoperative TTE	88 mL	42 mL	46 mL	52%
Postoperative TTE	89 mL	41 mL	48 mL	54%

Note: The data measured by Preoperative TTE included the ventricular aneurysm, and the data measured by Predicted TTE excluded the ventricular aneurysm.

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KEYWORDS

prosthetic heart valves; valve replacement; prosthetic-patient mismatch; ventricular aneurysm; suicide left ventricle.

ABBREVIATIONS

ICD = Implantable Cardioverter Defibrillator
BSA= Body Surface Area
BP = Blood Pressure
MV = Mitral Valve
TIMI = Thrombolysis in Myocardial Infarction
TTE = Transthoracic Echocardiography
IVS = Interventricular Septum
LVOT = Left Ventricular Outflow Tract
PG = Pressure Gradient
SAM = Systolic Anterior Motion
MR = Mitral Regurgitation
PPG = Peak Pressure Gradient
MPG = Mean Pressure Gradient
EOA = Effective Orifice Area
EOAI = Effective Orifice Area Index
LV-EDV = Left Ventricular End-Diastolic Volume
LV-ESV = Left Ventricular End-Systolic Volume
LV-SV = Left Ventricular Stroke Volume
LV-EF = Left Ventricular Ejection Fraction
PPM = Prosthetic-Patients Mismatch
TEE = Transesophageal Echocardiography
CT = Computed Tomography
MRI = Magnetic Resonance Imaging
LVOTO = Left Ventricular Outflow Tract Obstruction

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