CJC Open 3 (2021) 1406–1409

Case Report

Competitive Flow: Closure of Internal Thoracic Artery Graft After Successful Coronary Artery Bypass Graft Surgery

Ibrahim Mohsin, MD, MRCEM,[a] Lalith Namburu, MD,[b] Zaynah Sadiq, BS,[c] Brian Newberry, DO,[a] and Habeeb M. Ahmed, MD, FACC, MABHP, RVT[c]

[a] *Internal Medicine Residency Program, Norton Community Hospital, Norton, Virginia, USA*

[b] *Internal Medicine Residency Program, East Tennessee State University, Johnson City, Tennessee, USA*

[c] *Department of Cardiology, Kaaj HealthCare, San Jose, California, USA*

ABSTRACT

The internal thoracic artery has a patency rate of 85%-95% at 10-15 years post coronary artery bypass graft surgery. Development of total occlusion of the internal thoracic artery within a short period (< 6 months) after the surgery is exceedingly rare. However, competitive flow between the native vessel and the conduit internal thoracic artery, or competitive flow between the 2 conduit internal thoracic arteries in a multiple arterial grafting procedure can jeopardize 1 of the 2 conduit internal thoracic arteries. We report the cases of 2 patients who had bilateral internal thoracic artery grafts, with total occlusion of 1 of the 2 grafts within a short period (6 months) after successful coronary artery bypass graft surgery.

RÉSUMÉ

L'artère thoracique interne a un taux de perméabilité des greffons de 85 % à 95 % 10 à 15 ans après un pontage aortocoronarien. L'apparition d'une occlusion totale de l'artère thoracique interne dans un court délai (< 6 mois) après l'intervention est extrêmement rare. Cependant, le flux compétitif entre le vaisseau natif et l'artère thoracique interne de conductance ou le flux compétitif entre les 2 artères thoraciques internes de conductance dans une procédure de greffe artérielle multiple peuvent menacer l'une des 2 artères thoraciques internes de conductance. Nous rapportons les cas de 2 patients ayant subi une greffe bilatérale de l'artère thoracique interne et présenté une occlusion totale de l'un des 2 greffons peu (6 mois) après un pontage aortocoronarien réussi.

Since the inception of coronary artery bypass graft (CABG) surgery, various modifications in the CABG procedure have been made to improve graft patency, including choice of conduit, distal target selection, and sequential anastomotic technique. Closure of an internal thoracic artery (ITA) graft within 30 days of coronary artery bypass graft surgery is regarded as early graft failure and can be caused by excessive surgical manipulation, hypercoagulability, air or plaque embolization, preexisting graft pathology, mismatched conduit size, dissection, hematoma, spasm, or stenosis at the anastomosis site.[1] Occlusion of an ITA graft within 30 days after successful CABG surgery is rare, and its mechanism is not fully understood. One of the suggested mechanisms for such late postoperative-phase (after more than 1 month after CABG surgery) graft failure is competitive flow from the native vessels or grafts.[2] This case report aims to highlight the possibility of competitive flow between the native artery and an ITA graft, and between 2 ITA grafts, especially in the setting of sequential grafting, leading to shutdown of one of the ITA grafts, and further jeopardizing the flow in the native coronary arteries.

Case 1

A 58-year-old male with a medical history of hypertension, type 2 diabetes mellitus, mild hyperlipidemia, congestive heart failure, and coronary artery disease underwent a successful 4-vessel CABG for severe triple-vessel disease, with a graft from the left ITA to the left anterior descending artery (LAD), a jump graft of the right ITA to the diagonal artery and obtuse marginal artery, and a reverse autologous saphenous venous graft to the posterior descending artery. Follow-up approximately 6 weeks after the surgery showed complete resolution of angina symptoms.

Six months after the CABG surgery, the patient presented to the outpatient cardiology clinic with complaints of typical chest pain. The physical examination was unremarkable. An electrocardiogram revealed sinus rhythm with no significant

Received for publication May 12, 2021. Accepted June 28, 2021.

Ethics Statement: Verbal consent was obtained from the patients. We presented only de-identified data to ensure that the anonymity of the patients is maintained.

Corresponding author: Dr Ibrahim Mohsin, Department of Internal Medicine, Norton Community Hospital, 96 15th NW, Suite 104, Norton, Virginia 24273, USA. Tel.: +1-408-893-3808.

E-mail: ibrahim.mohsin@balladhealth.org

Data Availability: The findings in the case study and the supporting data can be obtained from the corresponding author upon request.

See page 1409 for disclosure information.

https://doi.org/10.1016/j.cjco.2021.06.017

Novel Teaching Points

- Competitive flow is a notable cause of late post operative phase graft failure following coronary artery bypass graft surgery.
- Intra operative graft flow assessment is helpful in providing anatomical and functional information to approach appropriate revasularization decisions.

ST−T changes. A transthoracic echocardiogram showed an ejection fraction of 60%-65%, with severe left ventricular hypertrophy, moderate bi-atrial enlargement, and moderate-to-severe right ventricle enlargement. The patient reported progressive worsening of anginal symptoms. Coronary angiography was performed that revealed occluded native LAD artery (Fig. 1A) and right coronary artery (RCA; Fig. 1B), atretic left ITA in its midportion (Fig. 1E), patent right ITA to obtuse marginal and diagonal arteries (Fig. 1C), and sub−totally occluded saphenous venous graft to RCA in its proximal portion (Fig. 1D). Further management was done by angioplasty and stenting of the saphenous venous graft and the left circumflex artery (Fig. 1F). Ventriculography revealed an ejection fraction of 60%-65%, with no regional wall motion abnormalities.

Case 2

A 55-year-old male with a medical history of hypertension, type 2 diabetes mellitus, mild hyperlipidemia, and coronary artery disease underwent successful 3-vessel CABG surgery for severe triple-vessel disease with a left ITA to left LAD artery graft, a right ITA to ramus artery graft, and a saphenous vein graft to the obtuse marginal artery. Follow-up approximately 6 weeks after the CABG surgery showed complete resolution of angina symptoms.

Five months after the CABG surgery, the patient presented to cardiac outpatient clinic with complaints of typical chest pain. The physical examination was unremarkable. An

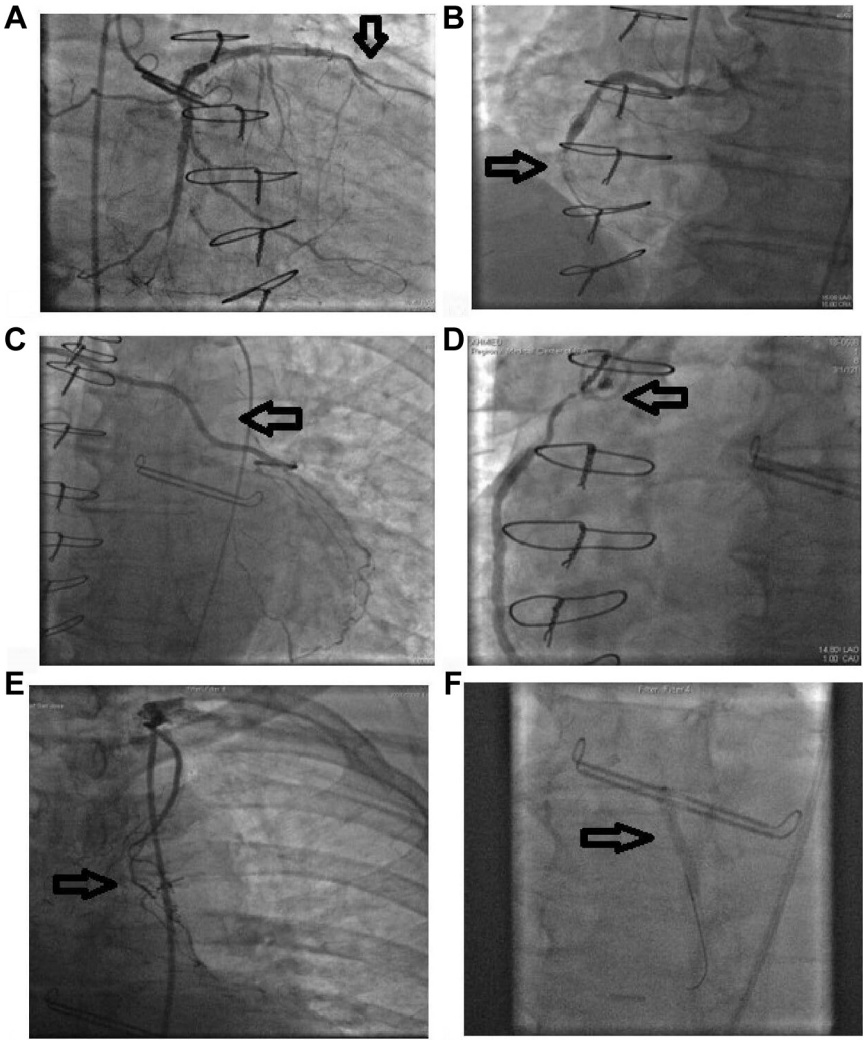

Figure 1. Images of coronary angiogram and intervention: (**A**) occluded left anterior descending artery; (**B**) occluded right coronary artery; (**C**) patent right internal thoracic artery to diagonal. (**D**) sub−totally occluded saphenous venous graft to posterior descending artery; (**E**) atretic left internal thoracic artery to left anterior descending artery; (**F**) angioplasty and stenting of the left circumflex artery.

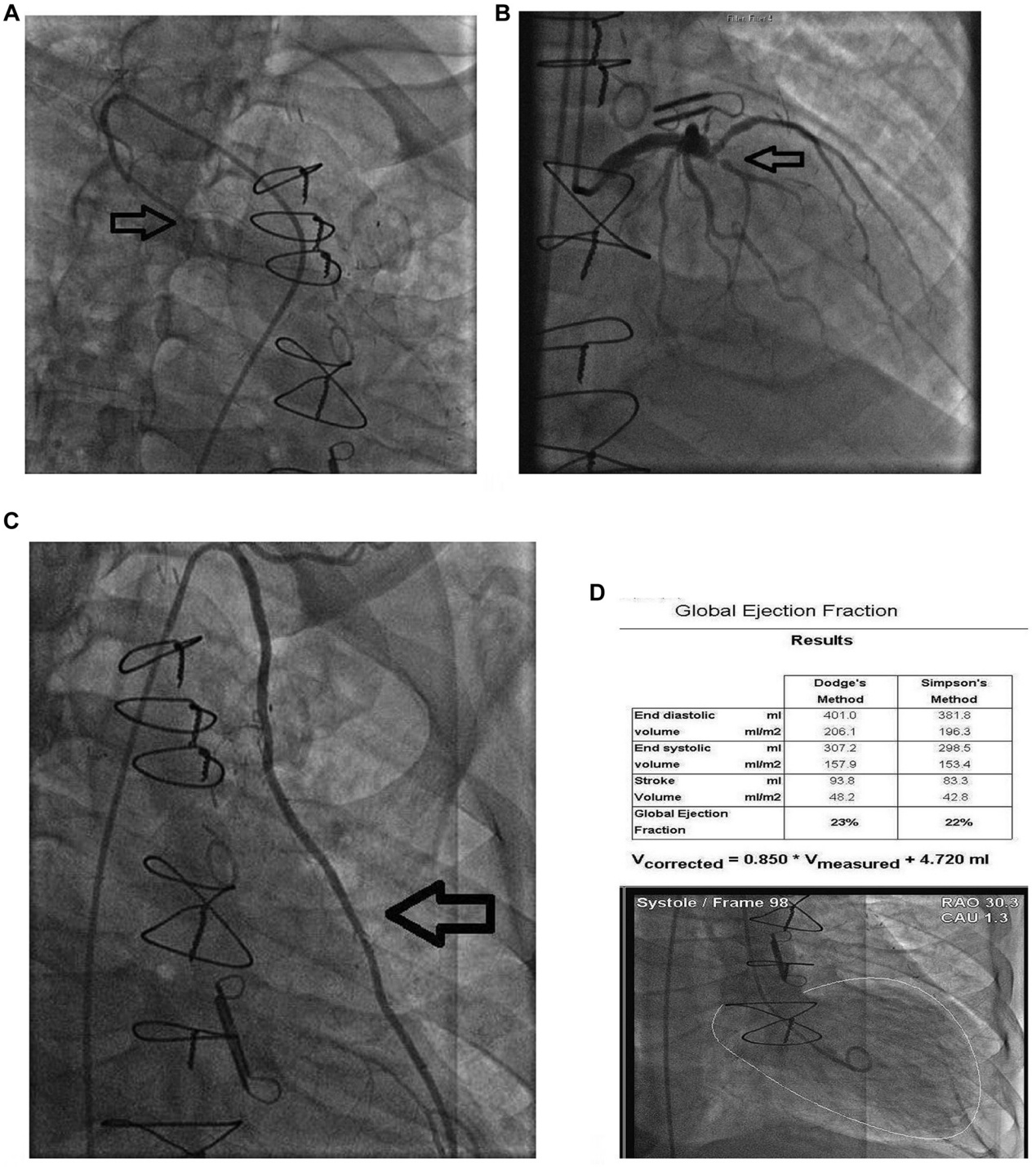

Figure 2. Images of coronary angiogram and intervention: (**A**) Occluded right internal thoracic artery to ramus artery; (**B**) occluded native diagonal; (**C**) patent left internal thoracic artery to left anterior descending artery; (**D**) ejection fraction determination during ventriculography.

electrocardiogram revealed sinus rhythm with no significant ST−T changes. A transthoracic echocardiogram showed an ejection fraction of 30%-35%, with moderate left atrial enlargement, and left ventricle hypertrophy. The Patient reported progressive worsening of anginal symptoms. Coronary angiography was performed that revealed the right ITA to ramus artery was atretic with minimal flow (Fig, 2A), the left ITA to LAD artery was patent (Fig. 2C), the native diagonal artery was occluded (Fig. 2B), and the saphenous vein graft to the obtuse marginal system was totally occluded. Further management was done by stage angioplasty and stenting of the native vessels. Ventriculography revealed an ejection fraction of 22% (Fig. 2D) and global hypokinesia with only base movement.

Discussion

The use of the left ITA for LAD artery grafting has been a cornerstone of CABG surgery. The patency of the left ITA has been reported to be 93% to 96% at 1 year, 88% to 94% at 5 years, and 85% to 90% at > 10 years.[3] Patency rates of the left ITA and right ITA at 5, 10, and 15 years are reported to be 98% and 96%, 95% and 81%, and 88% and 65%, respectively.[3] On long-term follow-up, use of multiple arterial conduits for CABG is associated with superior outcomes. Subsequently, over the past decade, the right ITA and the radial artery have emerged as competitors in being the second-best arterial conduit to supplement the left ITA.[4] The use of the right ITA as a second arterial graft has been shown to improve long-term survival, and provide superior freedom from reintervention, compared with the single −left ITA strategy.[5] In a separate study, the right ITA did not increase the incidence of 30-day mortality, and a mean follow-up of 5.7 years showed a reduction in the risk for late death.[6]

Graft failure is an analyzable event. Technical errors during the surgery, competitive flow, and innate graft characteristics are the most common factors that induce graft failure. Technical errors result in failure in the early postoperative phase (within 30 days) after CABG surgery, causing dissection, hematoma, spasm, or stenosis at the anastomotic site, and the string phenomenon. Late graft failure (beyond 1 year) is usually caused by atherosclerosis. Competitive flow, however, can cause graft failure in the late postoperative phase (after 30 days to 1 year), as in our case. Competitive flow is the struggle for flow between the native coronary arteries and the bypass graft. It is dependent on multiple factors such as stenosis severity, graft diameter, and graft length. CABG performed in a moderately stenotic and hemodynamically stable coronary artery lesion due to over-assessment leads to competitive flow between the ITA graft and the native coronary artery. This competitive flow can result in an occlusion of the ITA graft or the reversal of its flow.[7] The mechanism of competitive flow is much more complex with sequential grafting. Sequential grafting is a technique in which more than one distal anastomosis is constructed with one conduit. The advantages of sequential grafting include increased total graft flow through improved distal runoff, which contributes to improved flow and patency, and conservation of the conduit by reduction in the number of proximal aortic anastomoses.[8] However, in sequential composite bypass grafts, the interaction is between all the anastomosed branches within the composite graft, leading to a delay in pressure wave between grafts and coronary arteries, especially in the more distal ones.[7] The other disadvantage of this sequential grafting technique is the dependence of multiple grafts on a common inflow, with the possibility of catastrophic consequence in the event of proximal occlusion, as in our first case.

Transit-time flow measurements (TTFMs) help in intraoperative graft verification of competitive flow. Main graft flow (mL/min) and pulsatility index are the most important variables to assess with TTFMs. Any factor that increases the resistance to graft flow increases the pulsatility index value.[3] A small randomized study showed a significant correlation between low TTFM flow and graft occlusion at 1 year. Integration with intraoperative imaging to visualize the anastomosis morphology is another means of increasing TTFM sensitivity.[3] There can be a significant competitive flow between the native coronary arteries and the anastomosed conduits even though they may not seem to be connected. In the case of sequential grafts, competitive flow is much more complex, with closure of the grafts having disastrous effects, as the multiple distal arteries are dependent on a single proximal artery for their blood supply.

We recommend the use of an intraoperative graft flow assessment during CABG, with TTFMs, which provide anatomic and functional information to aid in making appropriate revascularization decisions.

Funding Sources

The authors have no funding sources to declare.

Disclosures

The authors have no conflicts of interest to disclose.

References

1. Pijls NH, Fearon WF, Tonino PA, et al. Fractional flow reserve versus angiography for guiding percutaneous coronary intervention in patients with multivessel coronary artery disease: 2-year follow-up of the FAME (fractional flow reserve versus angiography for multivessel evaluation) study. J Am Coll Cardiol 2010;56:177-84.

2. Nakajima H, Kobayashi J, Toda K, et al. A 10-year angiographic follow-up of competitive flow in sequential and composite arterial grafts. Eur J Cardiothorac Surg 2011;40:399-404.

3. Gaudino M, Antoniades C, Benedetto U, et al. Mechanisms, consequences, and prevention of coronary graft failure. Circulation 2017;136:1749-64.

4. Bello SOZ, Peng EWK, Sarkar PK. Conduits for coronary artery bypass surgery: the quest for second best. J Cardiovasc Med (Hagerstown) 2011;12:411-21.

5. Weiss AJ, Zhao S, Tian DH, Taggart TD, Yan A. meta-analysis comparing bilateral internal mammary artery with left internal mammary artery for coronary artery bypass grafting. Ann Cardiothorac Surg 2013;2:390-400.

6. Lytle BW, Blackstone EH, Sabik JF, et al. The effect of bilateral internal thoracic artery grafting on survival during 20 postoperative years. Ann Thorac Surg 2004;78:2005-12.

7. Dogan P, Kuyumcu M, Demiryapan E, Arisoy F, Ozeke O. Competitive coronary flow between the native left anterior descending artery and left internal mammary artery graft: Is it a surrogate angiographic marker of over-or-unnecessary revascularization decision in daily practice? Int J Angiol 2017;26:27-31.

8. Ouzounian M, Hassan A, Yip AM, et al. The impact of sequential grafting on clinical outcomes following coronary artery bypass grafting. Eur J Cardiothorac Surg 2010;38:579-84.