Postoperative coronary artery spasm after mitral valve replacement

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ABSTRACT

INTRODUCTION: Postoperative coronary artery spasm is an infrequent life-threatening event after cardiac surgery which can occur without an underlying coronary disease.

PRESENTATION OF CASE: We report a documented case of a 67-year-old man with normal coronary arteries submitted to mitral valve replacement. Immediately after surgery he had a ST elevation in the inferior leads, and an inferior wall hypokinesia at the trans-oesophageal echo. A coronary angiography demonstrated a focal spasm in the right coronary artery which was successfully treated by intracoronary injection of nitrates. The following postoperative course was uneventful and the left ventricular function returned to normal.

DISCUSSION: A coronary artery spasm should be suspected whenever a postoperative infarction occurs after valvular surgery especially in absence of associated coronary artery disease. In this case postoperative coronary angiography allows both the diagnosis and the treatment.

CONCLUSION: This case-report summarizes the findings of this rare and potentially life-threatening cause of early postoperative ischemia and highlights the role of early coronary angiography in the cases of suspected myocardial infarction after cardiac surgery.

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1. Background

Coronary artery spasm (POCAS) is a rare cause of postoperative ischemia [1]. The underlying mechanisms of spasm remain unclear, although an endothelial dysfunction seems to play a major role [2]. All cardiac surgical procedures are associated with an imbalance of the homeostasis that may promote POCAS, especially in association with coronary artery disease. Occasionally the spasm occurs in patients with valve disease as in our patient who was submitted to a mitral valve replacement and had apparently normal coronary arteries.

2. Case description

A 67-year-old man was admitted to hospital for the surgical treatment of a severe rheumatic mitral regurgitation. Preoperative coronary angiogram was unremarkable (Fig. 1A). The right coronary artery was dominant giving origin to large posterior descending and posterolateral arteries. In the left coronary system a single obtuse marginal originated from the circumflex artery which was of small caliber and exited the atrioventricular groove thereafter. The operation was carried through full median sternotomy and aorto-bicaval cardiopulmonary bypass. The mitral valve was exposed through a vertical transeptal bilateral atriotomy and replaced with a bileaflets mechanical prosthesis. The operative course was uneventful and the patient was transferred to the intensive care unit (ICU) on normal sinus rhythm and good cardiac function without inotropic support. Upon arrival in the ICU, a marked ST elevation became evident in inferior leads, while hemodynamic conditions remained stable. A transthoracic echocardiogram revealed hypokinetic inferior wall. A coronary angiography was performed: a focal, subocclusive spasm was evident in the middle to distal segment of the right coronary artery (Fig. 1B Video 1). An intracoronary injection of nitrates resulted in a prompt resolution of the spasm (Fig. 1C Video 2) and of the electrocardiographic changes. Continuous intravenous infusion of nitroglycerin (4 mg/h) and oral administration of diltiazem 60 mg twice a day were started. On postoperative day 2, intravenous nitroglycerin was changed to transdermal patch (10 mg/day). Subsequent postoperative course was uneventful and the patient was discharged in good clinical conditions on postoperative day 7. Transthoracic echocardiogram on discharge showed no abnormalities of regional kinesis.

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Table 1
Review of articles reporting coronary artery spasm following cardiac surgery. (References in the additional on-line material).

| Author                  | Ref. | No. of patients | Type of operation | Time of onset | Clinical manifestation | ECG changes | Angiographic localization of spasm | Treatment                      | Outcome            |
|-------------------------|------|-----------------|-------------------|---------------|-----------------------|-------------|-----------------------------------|-------------------------------|--------------------|
| Patients operated for coronary artery disease |      |                 |                   |               |                       |             |                                   |                               |                    |
| Buxton et al., 1981    | [12] | 6               | CABG              | <2 h          | Collapse             | STE, inferior | RCA                               | ICN, IVN                      | 3 survived, 3 died |
| Zeff et al., 1982      | [13] | 1               | CABG              | periop        | Haemodinamic instability | Na          | RCA                               | ICN                           | Survived           |
| Zingone et al., 1983   | [14] | 1               | CABG              | 5 h           | Angina                | STD, V2-V6   | Diffuse                           | ICN                           | Survived           |
| Donatelli et al., 1991a | [15] | 1               | CABG              | 6 h           | Haemodinamic instability | Na          | RCA                               | ICN, IVN, IVCCB            | Survived           |
| Caputo et al., 1999    | [16] | 1               | CABG              | 2 h           | Collapse              | STD, V1-V6   | LAD                               | ICN                           | Survived           |
| Trimble et al., 2003   | [17] | 1               | OPCAB             | 1 h           | Collapse, VF          | STE, diffuse | RCA                               | ICN                           | Survived           |
| Inokuchi et al., 2004  | [18] | 3               | CABG              | Na            | Haemodinamic instability | Na          | diverse                           | IVN, IVCCB, fasudil        | Survived           |
| Fukui et al., 2005     | [19] | 1               | OPCAB             | Na            | Haemodinamic instability | Na          | Diffuse                           | ICN, IABP                    | Survived           |
| Döpfner et al., 2005   | [20] | 1               | CABG              | 2 h           | VF                    | STE, lateral | Diffuse, Graft                    | IVN, LVAD                    | Survived           |
| Kaku et al., 2007      | [21] | 1               | CABG              | 20′           | Collapse, VT          | STE, inferior; AVB | RCA                               | ICN, CAS                     | Survived           |
| Guo et al., 2008       | [22] | 2               | CABG              | 4 h           | Angina                | ST modifications | LAD, RCA diffuse                   | ICN, IVCCB                  | Survived           |
| Carmeiro et al., 2010  | [23] | 1               | OPCAB             | 24 h          | Collapse, VF          | STE, V2-V5   | Diffuse                           | ICN, IABP                    | Survived           |
| Ju et al., 2011        | [24] | 1               | OPCAB             | <1 h          | Collapse              | STE, diffuse | Diffuse                           | ECMO                         | Survived           |
| Hosoba et al., 2012    | [25] | 1               | CABG              | 15 h          | Collapse              | STE, inferior | Diffuse                           | ICN, IVCCB, IABP           | Survived           |
| Patients operated for other cardiac conditions |      |                 |                   |               |                       |             |                                   |                               |                    |
| Tsuchida et al., 1993  | [26] | 1               | AVR               | 4 h           | Collapse              | STE, V4-V6   | Diffuse                           | ICN                           | Survived           |
| Kanno et al., 1994b    | [27] | 1               | MVR               | 2 h           | Collapse              | STE, inferior | RCA                               | IVCCB                        | Survived           |
| Kimura et al., 2006b   | [28] | 7               | Diverse           | intraop to 24 h | Collapse              | NA          | Diffuse, Grafts                    | IVN + MCS                    | 6 survived, 1 died   |
| Pinho et al., 2007     | [29] | 1               | AVR               | 1 h           | Collapse, VF          | STE, inferior | RCA                               | ICN                           | Survived           |
| Pragliola et al., 2007 | [30] | 1               | AVR               | 1 h           | Collapse, VF          | STD, inferior | Diffuse                           | ICN                           | Survived           |
| Sekine et al., 2007b   | [31] | 1               | Bentall           | 5 h           | Collapse              | STE, diffuse | Diffuse, left coronary             | IABP, ECMO                   | Died               |
| Guo et al., 2008       | [32] | 8               | Bentall           | 3 h           | Silent                | STE, V2-V6   | Diffuse, spasm of LAD              | IVN, IVCCB                  | Survived           |
| Casquero et al., 2009  | [33] | 1               | MVR, TVR          | 28 h          | Collapse, angina      | Na          | Diffuse                           | ICN                           | Survived           |
| Anselmi et al., 2013a  | [34] | 1               | TVR intraop       | 15 h          | Collapse              | STE, unweanable | Diffuse                           | ICN, ECMO                    | Dead               |
| Antevil et al., 2010   | [35] | 2               | MVR               | 28 h          | Collapse, angina      | Na          | LAD, RCA                         | ICN                           | Survived           |
| Ginsegi et al., 1981   | [36] | 1               | CABG              | intraop        | CPB unweanable        | STE, diffuse | Diffuse                           | ICN                           | Survived           |
| Shafei and Bennett, 1990 | [37] | 1               | CABG              | intraop        | CPB unweanable        | STE, inferior | Na                               | Support therapy           | Survived           |
| Yokoyama et al., 1990b | [38] | 1               | CABG              | intraop        | CPB unweanable        | Na          | Na                               | IVN                           | Survived           |
| Seki et al., 1991b     | [39] | 1               | OPCAB             | Na            | Collapse              | Na          | Na                               | IVN, IABP                    | Survived           |
| Kinoshita et al., 1991 | [40] | 1               | OPCAB             | Na            | Collapse, VT          | STE          | Na                               | IVN, IVCCB                  | Survived           |
| Minato et al., 1995b   | [41] | 1               | OPCAB             | Na            | Collapse              | Na          | Na                               | IVN, IVCCB                  | Survived           |
| Lin et al., 2007a      | [42] | 1               | OPCAB             | Na            | Collapse              | Na          | Na                               | IVN, IABP, ECMO             | Survived           |

ASDC, atrial septal defect closure; AVB, atriocavitary block; AVR, aortic valve replacement; CAS, coronary artery stenting; CABG, coronary artery bypass grafting; CPB, cardiopulmonary bypass; ECMO, extracorporeal membrane oxygenation; IABP, intraaortic balloon counterpulsation; IVCCB, intracoronary calcium channel blockers; ICN, intracoronary nitrates; IVCCB, intravenous calcium channel blockers; IVN, intravenous nitrates; LAD, left anterior descending; MR, mitral regurgitation; MVR, mitral valve replacement; Na, not available; OPCAB, off-pump coronary artery bypass; RCA, right coronary artery; SM, septal myectomy; STD, ST depression; STE, ST elevation; TVR, tricuspid valve repair; VF, ventricular fibrillation; VT, ventricular tachycardia.

a Article in Italian.
b Article in Japanese.
c Patient affected by carcinoid syndrome.
3. Discussion

Perioperative myocardial infarction is the first cause of early and log-term mortality after cardiac surgery [3]. Although the most common cause of postoperative ischemia after mitral valve surgery is a iatrogenic lesion to the circumflex artery [4], a coronary spasm [5] should always be considered among the possible causes of postoperative ischemia. It can be spontaneous or induced by surgical manipulation or pharmacological agents. It may also occur with or without an underlying atheromatous coronary disease: intense oxidative stress, inflammation and changes in vascular reactivity all lead to an increased propensity to spasm [6]. There are also diseases that predispose to coronary spasm, like the carcinoid syndrome [7].

Since 2006 [8] we have adopted a policy of immediate postoperative coronary angiography in cases of hemodynamic instability or dubious ECG interpretation. This allows a prompt diagnosis as well as in most cases the treatment of any possible spontaneous or iatrogenic condition [9]. However, in the last five years we could not observe any case of POCAS. The present one prompted us to accurately search the literature (Table 1).

The most common presentation of POCAS is upon arrival in the ICU up to 6 h after surgery. Usually it causes hemodynamic instability associated with ventricular arrhythmias and fibrillation. In some cases an extracorporeal membrane oxygenation (ECMO) support may be required to sustain the circulation and gain time to establish the diagnosis. When the spasm is limited to right coronary artery the electrocardiographic alterations are those of an inferior infarction, but ST changes can be subtle and difficult to interpret when the spasm is diffuse. The true incidence of POCAS is largely unknown. In the English literature, we could find 32 reports, including 7 small series, for a total number of 54 patients. In 9 of the reports a coronary angiography was not performed and the spasm was suspected as a result of the clinical presentation.

Some cases were considered intra-operative spasms, a condition that it is extremely difficult to ascertain. A recent case of intra-operative spasm occurred after the repair of a functional mitral regurgitation and was successfully detected and treated in a hybrid operating room by Antevil et al. [10].

POCAS is not a benign event. The mortality in the 54 cases collected from the literature was 11% and its incidence can be underestimated by its apparent rarity and difficult diagnosis. On the other hand, once angiographically documented, the treatment of POCAS is usually rapidly effective. The direct intracoronary injection of nitrates or calcium channel blockers promptly resolves the spasm. Devices to mechanically support the circulation (Intraaortic balloon pump; the ECMO or even a ventricular assist device) were used in 10 cases.

Despite the high early mortality the long-term prognosis of the patients successfully treated for POCAS is good. Buxton et al. performed an angiographic control at 3 and 12 months [11] in five of the six patients who developed a POCAS in his series. Direct intracoronary injection of ergonovine provoked a focal spasm in the right coronary artery in only in one case. It was concluded that the spasm does not recur after surgery, although some patients may have a predisposition to its development.

In conclusion, coronary artery spasm is an infrequent cause of ischemia after surgery. Postoperative ischemia should prompt a coronary angiography to rule out the spasm and allow immediate therapy.

References

[1] A. Maseri, S. Chierchia, Coronary artery spasm: demonstration, definition, diagnosis, and consequences, Prog. Cardiovasc. Dis. 25 (1982) 169–192.
[2] J. Brouzet, T. Mainar, V. Bordes, P. Ruiz-Nodar, J.M. Pineda, Severe spontaneous three-vessel coronary artery spasm, Valencia J. Int. J. Cardiol. 112 (2006) e53–e55.
[3] K.D. Larsen, I.S. Rubinfeld, Changing risk of perioperative myocardial infarction, Perm J. 16 (Fall) (2012) 4–9.
[4] E. Kilian, A. Beiras, A. Fernandez, B. Reichart, P. Lamm, Intraoperative assessment of circumflex occlusion during mitral valve operation, Ann. Thorac. Surg. (2011) 2271.
[5] K. Thygesen, J.S. Alpert, A.S. Jaffe, M.L. Simoons, B.R. Chaitman, H.D. White, Joint ESC/ACCF/AHA/WHF task force for universal definition of myocardial infarction, J. Am. Coll. Cardiol. 60 (October) (2012) 1518–1598.
[6] M.M. Ruel, T.A. Khan, P. Voisine, C. Bianchi, F.W. Sellke, Vasomotor dysfunction after cardiac surgery, Eur. J. Cardiothorac. Surg. 26 (2004) 1002–1014.
[7] S. Bhattacharyya, S. Raja, C. Toumpakis, M.E. Caplin, G.D. Dreyfus, J. Davar, Intraoperative coronary artery spasm complicating acute aortic valve replacement: implications for identification and treatment, Ann. Thorac. Surg. 83 (2007) 670–672.
[8] J.L. Antevil, A.L. Karavas, J.H. Selby, J.G. Byrne, Use of a hybrid operating room to diagnose and treat delayed coronary spasm after mitral valve repair, J. Thorac. Cardiovasc. Surg. 140 (2010) e25–e27.
[9] A.E. Buxton, J.W. Hirshfeld Jr, W.J. Untereker, S. Goldberg, A.H. Harken, L.W. Stephenson, R.N. Edie, Perioperative coronary arterial spasm: long-term follow-up, Ann. J. Cardiothorac. Surg. 35 (September) (1982) 444–451.
[10] A.E. Buxton, S. Goldberg, A. Harken, J. Hirshfeld Jr, J.A. Kastor, Coronary-artery spasm immediately after myocardial revascularization; recognition and management, N. Engl. J. Med. 304 (21) (1981) 1249–1253.
[11] R.H. Zeff, L.A. Iannone, C. Koutialwos, T.M. Brown, D.E. Gordon, M. Benson, S.J. Phillips, R.E. Alley, Coronary artery spasm following coronary artery revascularization, Ann. Thorac. Surg. 34 (1982) 196–200.
[12] B. Zingone, A. Salvi, B. Brancrini, Perioperative coronary artery spasm leading to myocardial ischaemia after vein graft surgery, Br. Heart J. 49 (March) (1983) 280–283.
[13] F. Donatelli, M.A. Mariani, M. Pocar, M. Triggiani, S. Pellegrini, A. Grossi, Intraoperative coronary artery spasm successfully treated with nitroglycerin and nifedipine, Ann. Thorac. Surg. 36 (1983) 97–100.
[14] M. Caputo, F. Nicolini, G. Franciossi, R. Gallotti, Coronary artery spasm after coronary artery bypass grafting, Eur. J. Cardiothorac. Surg. 15 (4) (1999) 545–548.
[15] S. Trimboli, G. Oppido, F. Santini, A. Mazzucco, Coronary artery spasm after off-pump coronary artery bypass grafting, Eur. J. Cardiothorac. Surg. 24 (5) (2003) 830–833.
[16] K. Inokuchi, A. Ito, Y. Fukushima, T. Matoba, A. Shiose, T. Nishida, M. Masuda, S. Morita, H. Shimokawa, Usefulness of fasudil, a Rho-kinase inhibitor, to treat
intractable severe coronary spasm after coronary artery bypass surgery, Cardiovasc. Pharmacol. 44 (3) (2004) 275–277.
[19] T. Fukui, S. Takahashi, Y. Hosoda, Coronary artery and graft spasm after off-pump coronary artery bypass grafting, Jpn. J. Thorac. Cardiovasc. Surg. 53 (2005) 109–113.
[20] U.R. Döpfner, J.P. Braun, J. Grosse, W. Konertz, Temporary left ventricular assist and leovisemendan for coronary artery spasm, Interact. Cardiovasc. Thorac. Surg. 4 (2005) 316–318.
[21] B. Kaku, M. Ikeda, H. Kato, S. Takabatake, T. Hayashi, T. Taguchi, Y. Niita, Y. Hiraia, S. Ao, Coronary artery multistenting in the treatment of life-threatening refractory coronary spasm after coronary artery bypass grafting, Int. Heart J. 48 (2007) 379–385.
[22] L.R. Guo, M.L. Myers, E.L. Kuntz, Coronary artery spasm: a rare but important cause of postoperative myocardial infarction, Ann. Thorac. Surg. 86 (2008) 994–995.
[23] J.D. Carneiro Neto, J.A. Lima Neto, R.M. Simões, N.A. Stolf, Coronary-artery spasm after mitral valve replacement, Interact. Cardiovasc. Thorac. Surg. 8 (2008) 670–672.
[24] M.H. Ju, J.B. Kim, H.J. Kim, S.J. Choo, Refractory coronary artery spasm after mitral valve replacement, Eur. J. Cardiothorac. Surg. 36 (2009) 191.
[25] A. Anselmi, H. Corbione, D. Boulmier, V.G. Ruggieri, Early diffuse coronary artery spasm after heart valve surgery in the carcinoid syndrome, J. Card. Surg. 28 (2013) 402–403.
[26] R. Ginsburg, E.B. Stinson, M.R. Bristow, J.S. Schroeder, Coronary-artery spasm after revascularization, N. Engl. J. Med. 305 (1981) 699.
[27] S. Hosoba, T. Suzuki, N. Takashima, T. Kinoshita, S. Kuryanagi, H. Nota, T. Asai, M.H. Ju, J.B. Kim, H.J. Kim, S.J. Choo, Refractory coronary artery spasm after off-pump coronary artery bypass grafting, ANZ J. Surg. 77 (2007) 395–400.
[28] M. Yokoyama, T. Yamada, H. Nakahara, N. Oshima, S. Tanabe, Y. Irie, H. Sano, Two cases of perioperative coronary vasospasm following ASD closure and OMC, Kyobu Geka 43 (1990) 891–894.
[29] K. Seki, R. Kuriharyashi, T. Sakurada, S. Sekine, H. Aida, T. Abe, T. Syu, K. Tsuchida, Coronary artery spasm after aortic valve replacement: a case report, Kyobu Geka 44 (1991) 176–179.
[30] S. Imanishi, K. Matsu, M. Itami, T. Asou, M. Masuda, Y. Kawachi, K. Tokunaga, A new aspect of coronary artery spasm induced by cardiac surgery, Jpn. J. Surg. 21 (1991) 395–401.
[31] M.S. Urrea Ramos, S. Celaya Lara, J.A. Santibáñez Salgado, V. Lozano Torres, V. Herrera Alarcón, S. Estrada Dávalos, F. Rucinque Acevedo, V. Araya Gómez, Improved coronary artery perfusion and favorable surgical outcome after aortic valve replacement, Arch. Inst. Cardiol. Mex. 64 (1994) 315–318.
[32] N. Kimura, K. Kawahito, K. Adachi, H. Murata, A. Yamaguchi, H. Adachi, T. Ino, Effects of intra-coronary and intra-graft administration of nicorandil for coronary artery spasm after coronary artery bypass grafting, Kyobu Geka 59 (2006) 71–77.
[33] T. Pinho, J. Almeida, M. García, P. Pinho, Coronary artery spasm after aortic valve replacement, Interact. Cardiovasc. Thorac. Surg. 6 (2007) 387–388.
[34] C. Pragliola, L. Altamura, G. Niccoli, M. Siviglia, S. De Paulis, G.F. Possati, Postoperative coronary artery spasm complicating aortic valve replacement: implications for identification and treatment, Ann. Thorac. Surg. 83 (2007) 994–995.
[35] Y. Sekine, M. Kitano, T. Akimoto, K. Matsuda, Perioperative coronary spasm in the modified Bentall’s operation for localized dissecting aneurysm of valsalva sinuses, Kyobu Geka 60 (2007) 794–799.
[36] E. Casquero, D. Durán, V. Asorey, R. Casais, Coronary artery spasm after mitral and tricuspid anuoplasty, Eur. J. Cardiothorac. Surg. 36 (2009) 191.
[37] K. Tsuchida, T. Takemura, M. Kijima, S. Matsumoto, Coronary artery spasm after aortic valve replacement, Eur. J. Cardiothorac. Surg. 4 (1990) 396–400.
[38] A. Anselmi, H. Corbione, D. Boulmier, V.G. Ruggieri, Early diffuse coronary artery spasm after heart valve surgery in the carcinoid syndrome, J. Card. Surg. 28 (2013) 402–403.
[39] R. Ginsburg, E.B. Stinson, M.R. Bristow, J.S. Schroeder, Coronary-artery spasm after revascularization, N. Engl. J. Med. 305 (1981) 699.
[40] H. Shafei, J.G. Bennett, Coronary artery spasm during mitral valve replacement, Eur. J. Cardiothorac. Surg. 4 (1990) 396–400.
[41] M. Yokoyama, T. Yamada, H. Nakahara, N. Oshima, S. Tanabe, Y. Irie, H. Sano, Two cases of perioperative coronary vasospasm following ASD closure and OMC, Kyobu Geka 43 (1990) 891–894.
[42] K. Seki, R. Kuriharyashi, T. Sakurada, S. Sekine, H. Aida, T. Abe, T. Syu, K. Tsuchida, Coronary artery spasm after aortic valve replacement: a case report, Kyobu Geka 44 (1991) 176–179.
[43] K. Kinoshita, K. Matsu, M. Mayumi, T. Asou, M. Masuda, Y. Kawachi, K. Tokunaga, A new aspect of coronary artery spasm induced by cardiac surgery, Jpn. J. Surg. 21 (1991) 395–401.
[44] M.S. Urrea Ramos, S. Celaya Lara, J.A. Santibáñez Salgado, V. Lozano Torres, V. Herrera Alarcón, S. Estrada Dávalos, F. Rucinque Acevedo, V. Araya Gómez, Intraoperative circulatory collapse due to a coronary spasm following successful coronary revascularization, Arch. Inst. Cardiol. Mex. 64 (1994) 67–72.
[45] N. Minato, T. Itoh, M. Natsu, K. Furukawa, K. Rikikate, H. Yamamoto, Perioperative coronary artery spasm in modified Bentall’s operation for annulo-aortic ectasia in Marfan’s syndrome: A case report of perioperative chordal rupture of the mitral valve, J. Cardiovasc. Surg. (Torino) 36 (1995) 153–157.
[46] C.Y. Lin, Z.C. Weng, S.H. Loh, G.J. Hong, C.S. Tsai, Coronary artery spasm after off-pump coronary artery bypass grafting, ANZ J. Surg. 77 (2007) 126–129.
[47] S. Sawaki, A. Matsuura, H. Ito, S. Saito, H. Takemura, K. Miyahara, S. Aoki, Coronary artery multistenting in the treatment of life-threatening refractory coronary spasm after coronary artery bypass grafting, Kyobu Geka 63 (2010) 102–105.