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Review

Merits of and Technical Tips for Supra-Mesenteric Aortic Cross Clamping

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Supra-celiac aortic cross clamping is often utilized during aortic reconstruction for aneurysmal/occlusive disease involving the pararenal aorta. However, this may be accompanied a myriad of complications related to hemodynamic disturbances, cardiopulmonary compromise and hepatic ischemia. Supra-mesenteric aortic cross clamping may be an excellent option in selected patients with suitable anatomy to minimize or avoid these complications. Herein, the merits of and technical tips for supra-mesenteric aortic cross clamping are discussed.

Key Words: Aorta, Clamping, Celiac artery, Superior mesenteric artery, Arterial bypass

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INTRODUCTION

Suprarenal aortic cross clamping (AXC) is usually employed during open aortic reconstruction (OAR) for pararenal abdominal aortic aneurysm or aortic occlusive disease with atherosclerotic disease/thrombus burden extending up to the renal arteries [1]. However, it can be fraught with complications if the suprarenal segment is shaggy or has aneurysmal changes. In such cases, supra-celiac aortic cross clamping (SCXC) is often utilized. While it can be done safely and effectively [2-5], it also can be accompanied by its own complications related to increased blood loss, coagulopathy, hemodynamic and cardiopulmonary disturbances and spinal cord ischemia [2]. Supra-mesenteric (superior mesenteric artery [SMA]) aortic cross clamping (SMXC) may be an excellent option in selected patients with suitable anatomy to minimize or avoid these complications [6].

AXC initiates hemodynamic disturbances resulting in ischemic injury to the organs distal to the clamp site and a most complex cascade of ischemia-induced humoral responses. Unclamping of the aorta causes hypotension, ischemia-reperfusion injury of organs and washout of mediators that suppress myocardial function and cause injury of remote organs such as the lungs [6]. The degree and extent of these hemodynamic and pathophysiologic disturbances are determined by the level and duration of AXC, as well as preoperative cardiac, pulmonary and renal functions [7-9].

While the most salient and uniform hemodynamic response to AXC is arterial hypertension, other effects include changes in filling pressures and cardiac output that are determined by clamp location. With SCXC, blood volume redistribution occurs from the splanchnic and nonsplanchnic vascular beds towards the heart [10,11]. This increases the preload and blood volume to organs proximal to the supraceliac aorta. The increases in both preload and afterload with SCXC lead to an increased myocardial contractility and myocardial oxygen demand compared with infra-celiac aortic cross clamping (ICXC), which produces inconsistent hemodynamic responses. Blood volume may be redistributed to the heart, increasing the preload, or it may be redistributed to splanchnic circulation, without an increase in preload. The distribution of blood volume between the splanchnic and nonsplanchnic vasculature is determined by blood volume status, splanchnic vascular tone, depth of anesthesia, pharmacodynamics of the anesthetic, and other factors [7].

These differences in hemodynamic responses lead to different downstream effects and consequences. If the heart is incapable of responding with increased myocardial contractility after SCXC, cardiac decompensation follows with potentially grave intraoperative and postoperative consequences. ICXC does not necessarily mandate increased myocardial contractility and oxygen demand and therefore carries less risk of adverse coronary events than SCXC [12,13]. Since patients requiring OAR often have concomitant coronary artery disease with limited coronary reserve, avoiding SCXC is desirable when anatomically and technically feasible.

Another benefit of SMXC is preservation of hepatic blood flow. Hepatic ischemia may induce disseminated intravascular coagulopathy [14], depletion of clotting factors from hepatocyte necrosis [15-17], microscopic intravascular thrombosis [18], primary fibrinolytic pathway activation secondary to reduction of tissue plasminogen activator clearance [19,20] and consumptive coagulopathy [18,21].

Humoral responses to ischemia and ischemia-reperfusion injury include a cascade of events: activation of the renin-angiotensin system, release of catecholamines and discharge of the sympathetic nervous system, release of oxygen free radicals, prostaglandins, endotoxins, cytokines (both pro- and anti-inflammatory) and other mediators. The degree and extent of these responses are, again, dependent on the level of AXC. Visceral ischemia causes a marked increase in systemic levels of the cytokines including tumor necrosis factor α, interleukin (IL)-6, IL-8 and IL-1 [22,23], which in turn is associated with a higher incidence of mortality and multisystem organ dysfunction.

Furthermore, it may also contribute to pulmonary injury. In an experimental model, severe pulmonary damage was induced by release of a large amount of xanthine oxidase, altering capillary membrane integrity and resulting in pulmonary injury [24]. Clinical benefits of shunting of the celiac axis and SMA during thoracoabdominal aortic repair have also been reported [25,26].

Celiac blood flow may be compromised to a certain extent with SMXC (akin to up to 30% reduction in renal blood flow with infrarenal AXC). Nonetheless, in patients with suitable anatomy, preservation of hepatic blood flow during OAR with SMXC may be preferred to SCXC so as to minimize/avoid hepatic ischemia-induced coagulopathy, undue myocardial stress and other remote organ injury [1]. Essential anatomic suitability to perform SMXC includes 1) a minimum distance of 8 mm between the SMA and celiac axis; 2) no radiological or intraoperative evidence of aneurysmal degeneration, thrombus or calcification at the clamp site. It is preferable that the gastroduodenal arcade is intact.

TECHNIQUE

There are three different approaches to the paravisceral aorta: retroperitoneal, transperitoneal retropancreatic and transperitoneal medial visceral rotation. In this report, the discussion will be limited to the transperitoneal retropancreatic approach.

Via a midline trans-peritoneal incision, the infrarenal aorta is exposed in a standard fashion by reflecting the transverse colon superiorly and the small bowel to the right. It is better to divide and ligate the para-aortic tissue with silk ligature, rather than with electrocautery, so as to prevent lymphatic leak and chylous ascites formation. The left renal vein (LRV) may be divided or mobilized free. If it is to be divided, it should be divided to the right of the adrenal vein. It is the authors' preference not to divide the vein. In that case, the LRV is fully mobilized by dividing the left adrenal and lumbar veins; rarely the left gonadal vein

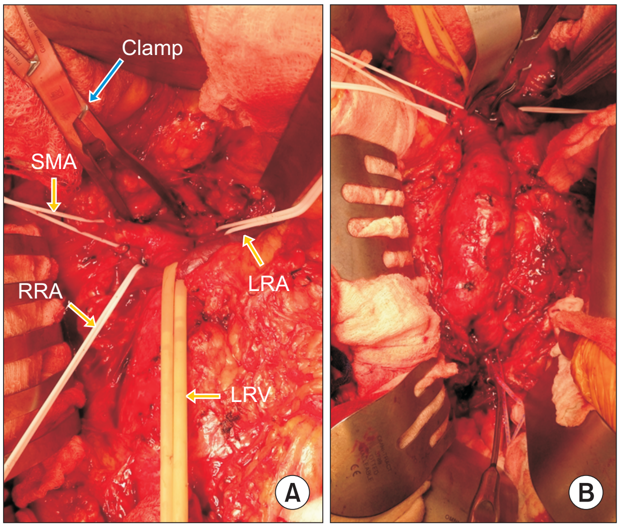

Fig. 1. (A) The superior mesenteric artery (SMA), right renal artery (RRA) left renal artery (LRA) are encircled with vessel loops and left renal vein (LRV) with a yellow plasma tubing. An aortic clamp is positioned on supra-mesenteric aorta. (B) In the same patient, the LRV is retracted with a renal retractor blade and aortic cross clamp applied on the supra-mesenteric aorta providing uninhibited access to the pararenal aorta.

division is required (Fig. 1). If LRV division is still required after these maneuvers, the vein is divided between clamps and reanastomosed upon completion of the procedure with a 5-0/6-0 Prolene suture. Bilateral renal arteries are isolated and dissected free.

The pancreas is retracted (using a renal vein retractor of Omni retractor system) antero-superiorly and dissection continued along the anterior aspect of the suprarenal aorta at 1 o'clock orientation towards the SMA. The surgeon should be cognizant of the location of the SMA throughout this portion of the operation by localizing it with either finger palpation or continuous wave Doppler in order to avoid injury to the SMA. The periaortic tissue, including the dense autonomic ganglia along the anterolateral surface of the aorta is divided with care taken to avoid injury to the SMA. Once the SMA is reached at its origin, it is encircled with a vessel loop. Dissection is continued cephalad at 1 o'clock along the supra-SMA aorta. The left crus of the diaphragm is divided with electrocautery to facilitate exposure of the paravisceral aorta. The aorta is retracted to the right using a sucker to avoid injury to the aorta (Fig. 2). This allows sufficient room for eventual placement of an aortic clamp and mobilization of the aorta to the left of the patient. Dissection at the supra-SMA aorta is then continued to the right side of the aorta. Blunt dissection using a small suction tip is most helpful. The plane of dissection is kept along the anterior aspect of the aorta and continued to the right side of the aorta between the aorta and the right crus of the diaphragm. With the left crus being divided, the aorta is easily mobilized to the left and enough room is created for clamp placement. On rare occasion, the right crus division is needed to create room for clamp placement. By continuing the dissection proximally, it is also possible in thin patients to reach the celiac axis and the supraceliac aorta (Fig. 3A, B).

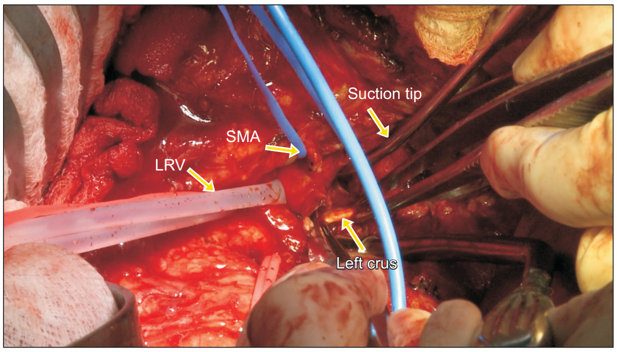

Fig. 2. The left crus of the diaphragm is held between a pair of forces before it is divided with electrocautery, while the aorta is pushed to the right using a sucker tip to avoid any thermal injury to the aorta. SMA, superior mesenteric artery; LRV, left renal vein.

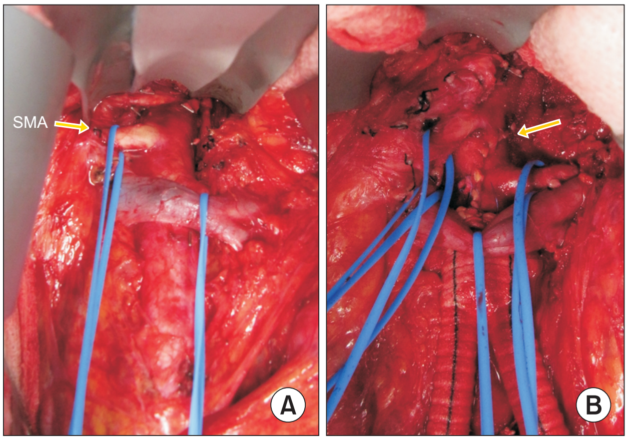

Fig. 4. (A) The paravisceral aorta and superior mesenteric artery (SMA) are exposed by a transperitoneal retropancreatic approach. (B) Pararenal aortic endarterectomy is performed via a longitudinal aortotomy which is closed primarily (arrow). The aortic clamp was moved down to the infrarenal aorta, the aorta transected and a prosthetic graft sewn in end-to-end.

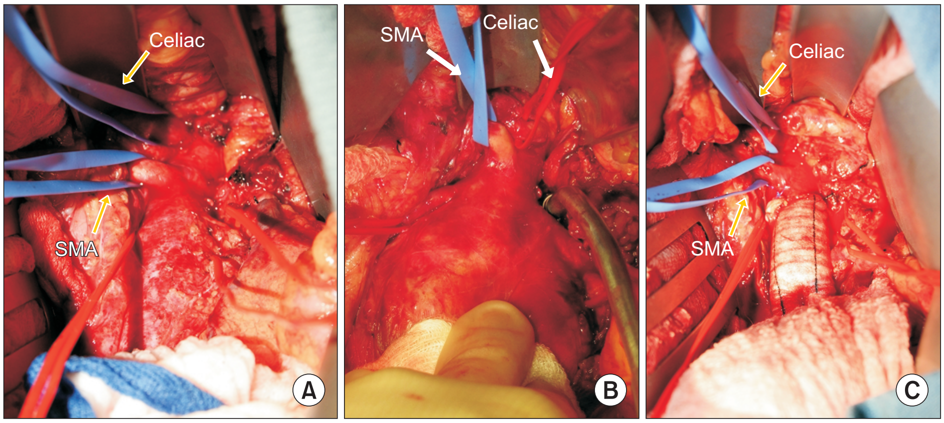

Fig. 3. (A, B) Both the superior mesenteric artery (SMA) and celiac axis are isolated and dissected free. Red loops encircle the bilateral renal arteries. (C) Surgical graft is in place.

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Distal control is obtained at the desired level, whether it be at the iliac or femoral arteries. After systemic heparinization, clamps are placed where it is non-diseased (no thrombus burden) so as to minimize the risk of distal atheroembolization. The aortic reconstruction is then performed in the standard fashion (Fig. 3C, 4).

CONCLUSION

SCXC is often utilized during aortic reconstruction for pararenal abdominal aortic aneurysm and occlusive disease extending up to the renal arteries. However, this may be accompanied by hepatic ischemia-induced coagulopathy, hemodynamic and cardiopulmonary disturbances, myocardial stress and spinal cord ischemia. Supra-SMA AXC may be an excellent option in selected patients with suitable anatomy to minimize or avoid these complications. Vascular surgeons should be familiar with this transperitoneal retropancreatic approach to the SMA, which may help avoid complications associated with SCXC.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

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REFERENCES

1) Lim S, Halandras PM, Saqib NU, Ching YA, Villella E, Park T, et al. Comparison of supramesenteric aortic cross-clamping with supraceliac aortic cross-clamping for aortic reconstruction. J Vasc Surg 2016;64:941-947.
2) Nypaver TJ, Shepard AD, Reddy DJ, Elliott JP Jr, Ernst CB. Supraceliac aortic cross-clamping: determinants of outcome in elective abdominal aortic reconstruction. J Vasc Surg 1993; 17:868-875.
3) Jean-Claude JM, Reilly LM, Stoney RJ, Messina LM. Pararenal aortic aneurysms: the future of open aortic aneurysm repair. J Vasc Surg 1999;29:902-912.
4) Chong T, Nguyen L, Owens CD, Conte MS, Belkin M. Suprarenal aortic cross-clamp position: a reappraisal of its effects on outcomes for open abdominal aortic aneurysm repair. J Vasc Surg 2009;49:873-880.
5) Jeyabalan G, Park T, Rhee RY, Makaroun MS, Cho JS. Comparison of modern open infrarenal and pararenal abdominal aortic aneurysm repair on early outcomes and renal dysfunction at one year. J Vasc Surg 2011;54:654-659.
6) Moore EE, Maier RV, Hoyt DB, Jurkovich GJ, Trunkey DD. Acute care surgery: Eraritjaritjaka. J Am Coll Surg 2006;202:698-701.
7) Gelman S. The pathophysiology of aortic cross-clamping and unclamping. Anesthesiology 1995;82:1026-1060.
8) Roizen MF, Beaupre PN, Alpert RA, Kremer P, Cahalan MK, Shiller N, et al. Monitoring with two-dimensional transesophageal echocardiography. Comparison of myocardial function in patients undergoing supraceliac, suprarenal-infraceliac, or infrarenal aortic occlusion. J Vasc Surg 1984;1:300-305.
9) Thompson JP, Boyle JR, Thompson MM, Strupish J, Bell PR, Smith G. Cardiovascular and catecholamine responses during endovascular and conventional abdominal aortic aneurysm repair. Eur J Vasc Endovasc Surg 1999;17:326-333.
10) Eide TO, Aasland J, Romundstad P, Stenseth R, Saether OD, Aadahl P, et al. Changes in hemodynamics and acid-base balance during cross-clamping of the descending thoracic aorta. A study in patients operated on for thoracic and thoracoabdominal aortic aneurysm. Eur Surg Res 2005;37:330-334.
11) Gelman S, Reves JG, Fowler K, Samuelson PN, Lell WA, Smith LR. Regional blood flow during cross-clamping of the thoracic aorta and infusion of sodium nitroprusside. J Thorac Cardiovasc Surg 1983;85:287-291.
12) Grindlinger GA, Vegas AM, Manny J, Bush HL, Mannick JA, Hechtman HB. Volume loading and vasodilators in abdominal aortic aneurysmectomy. Am J Surg 1980;139:480-486.
13) Gooding JM, Archie JP Jr, McDowell H. Hemodynamic response to infrarenal aortic cross-clamping in patients with and without coronary artery disease. Crit Care Med 1980;8:382-385.
14) Cohen JR, Angus L, Asher A, Chang JB, Wise L. Disseminated intravascular coagulation as a result of supraceliac clamping: implications for thoracoabdominal aneurysm repair. Ann Vasc Surg 1987;1:552-557.
15) Levy PJ, Tabares AH, Olin JW, Tuthill RJ, Gottlieb A, Sprung J. Disseminated intravascular coagulation associated with acute ischemic hepatitis after elective aortic aneurysm repair: comparative analysis of 10 cases. J Cardio-

thoracic Vasc Anesth 1997;11:141-148.

16) Levy PJ, Sprung J, Tabares AH, Novick AC, O'Hara JF Jr. Unexplained intraoperative hypotension, acute ischemic hepatitis, and pancreatitis associated with aortorenal bypass surgery. J Cardiothorac Vasc Anesth 1997;11:767-770.

17) Sprung J, Levy PJ, Tabares AH, Gottlieb A, Schoenwald PK, Olin JW. Ischemic liver dysfunction after elective repair of infrarenal aortic aneurysm: incidence and outcome. J Cardiothorac Vasc Anesth 1998;12:507-511.

18) Gertler JP, Cambria RP, Brewster DC, Davison JK, Purcell P, Zannetti S, et al. Coagulation changes during thoracoabdominal aneurysm repair. J Vasc Surg 1996;24:936-943.

19) Illig KA, Green RM, Ouriel K, Riggs PN, Bartos S, Whorf R, et al. Primary fibrinolysis during supraceliac aortic clamping. J Vasc Surg 1997;25:244-251.

20) Haithcock BE, Shepard AD, Raman SB, Conrad MF, Pandurangi K, Fanous NH. Activation of fibrinolytic pathways is associated with duration of supraceliac aortic cross-clamping. J Vasc Surg 2004;40:325-333.

21) Anagnostopoulos PV, Shepard AD, Pipinos II, Raman SB, Chaudhry PA, Mishima T, et al. Analysis of coagulation changes associated with supraceliac aortic crossclamping using thromboelastography. J Surg Res 2001;98:52-58.

22) Welborn MB, Oldenburg HS, Hess PJ, Huber TS, Martin TD, Rauwerda JA, et al. The relationship between visceral ischemia, proinflammatory cytokines, and organ injury in patients undergoing thoracoabdominal aortic aneurysm repair. Crit Care Med 2000;28:3191-3197.

23) Hill GE, Mihalakakos PJ, Spurzem JR, Baxter TB. Supraceliac, but not infrarenal, aortic cross-clamping upregulates neutrophil integrin CD11b. J Cardiothorac Vasc Anesth 1995;9:515-518.

24) Weinbroum A, Nielsen VG, Tan S, Gelman S, Matalon S, Skinner KA, et al. Liver ischemia-reperfusion increases pulmonary permeability in rat: role of circulating xanthine oxidase. Am J Physiol 1995;268:G988-G996.

25) Eide TO, Myhre HO, Saether OD, Aadahl P. Shunting of the coeliac and superior mesenteric arteries during thoracoabdominal aneurysm repair. Eur J Vasc Endovasc Surg 2003;26:602-606.

26) Cambria RP, Davison JK, Giglia JS, Gertler JP. Mesenteric shunting decreases visceral ischemia during thoracoabdominal aneurysm repair. J Vasc Surg 1998;27:745-749.

https://doi.org/10.5758/vsi.2019.35.2.55