Technique of Superior Vena Cava Resection for Lung Carcinomas

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Lung cancer or primary malignant tumors of the mediastinum occasionally invades the superior vena cava (SVC). Although tumor involvement of the SVC is an uncommon presentation, its presence does not preclude a R0 resection provided the surgeon is familiar with the techniques used to resect and reconstruct the SVC in conjunction with the planned pulmonary resection. The pulmonary resection is almost always a right upper lobectomy or less commonly a right pneumonectomy.

Several groups have documented the safety and efficacy of combined caval and pulmonary resection in appropriately selected patients. The majority of these patients have primary non-small cell lung cancer (NSCLC) and many have undergone induction therapy with chemotherapy and/or radiation. The primary reason for SVC resection is tumor (T) involvement (75%), with the remainder secondary to caval involvement by adjacent nodal (N) disease. A review of the literature reveals over 280 patients who underwent SVC resection with approximately 30% requiring placement of a prosthetic graft. The average mortality for the entire group is 11% with a 5-year survival for all patients of 25%.

Given that NSCLC invasion of the SVC is a T4 lesion, it is imperative that a thoughtful approach to staging and preoperative planning be done before embarking on this procedure. The reason for this is that no single institution has significant experience with the procedure and it is attended by a relatively significant morbidity and mortality. Noninvasive staging procedures (computed tomography–positron emission tomography) should routinely be performed, mainly to rule out M1 disease but also to give a clue to the presence of N2 nodal disease. I also routinely get a computed tomography of the chest with intravenous contrast to assess SVC and related innominate vein patency, degree of SVC narrowing, presence of intraluminal thrombus, and the amount of venous collateralization. A staging mediastinoscopy should be performed before any planned resection as the presence of N2 nodal disease, particularly if multi-station is a contraindication to resection. Depending on the degree of SVC obstruction and associated venous collateral formation, a mediastinoscopy may be relatively contraindicated given the risk of bleeding. Under these circumstances the preferred invasive staging approach is endobronchial ultrasound-guided fine-needle aspiration of N2 nodes with esophageal ultrasonography biopsy of posterior station 7, 8 or other nodes as necessary. A bronchoscopy is also required as right mainstem or proximal right upper lobe bronchus involvement suggests the need for a concomitant bronchial or tracheal sleeve resection and this may affect the choice of surgical approach.

The purpose of this article is to describe the techniques necessary to safely resect, and reconstruct if necessary, the SVC to achieve an oncologically acceptable result. The paradigm used throughout the technical description of the procedure is that of a right upper lobe NSCLC invading the SVC as that is the most common clinical scenario.

Operative Technique

Patients should have a double-lumen endotracheal tube and a large-bore intravenous line placed in their groin. In addition, removal of any existing long-term indwelling venous catheters in the subclavian or jugular venous systems should be performed.

The majority of the patients with right upper lobe tumors involving the SVC can be approached through a right posterolateral thoracotomy in the fourth or fifth intercostal space. Although cardiopulmonary bypass is very uncommon in these patients, the choice of a median sternotomy does facilitate its use if indicated (Fig. 1A). The fourth intercostal space is often preferable particularly when the tumor extends into or is in close proximity to the right and left innominate veins and more proximal control of the SVC is anticipated.

Although cardiopulmonary bypass is very uncommon in these patients, the choice of a median sternotomy does facilitate its use if indicated (Fig. 1B). This approach is also better for primary mediastinal tumors involving the SVC. In addition, a median sternotomy may be preferred in patients who require reconstruction of the left innominate vein directly from the right atrium. Finally, a concomitant right upper lobectomy is actually technically quite easy through a sternotomy, and therefore, should not dissuade the surgeon from considering this approach. Technical challenges that can present with a median sternotomy include performing a complete subcarinal nodal dissection and the management of a challenging intraparenchymal fissure.
Figure 1 Surgical incisions used to approach SVC resection and reconstruction. (A) A posterolateral thoracotomy, usually through the fourth or fifth intercostal space, is the most commonly used approach. (B) A median sternotomy should be considered for mediastinal tumors involving the SVC or possibly if a right carinal pneumonectomy is needed. (C) A right hemi-clamshell incision can also be performed and may be helpful for tumors that also require a significant amount of posterior mediastinal dissection.
A right hemi-clamshell approach has also been used for tumors invading the SVC (Fig. 1C). This approach allows control of the SVC and associated vasculature, particularly the right subclavian, jugular, and left innominate venous systems. It also permits a better view of the posterior right hemithorax. This may be of benefit for those tumors that are large and require either a concomitant chest wall resection or lysis of extensive posterior adhesions following a course of induction therapy. In addition, for those patients needing a right upper lobe sleeve resection or a right pneumonectomy, this approach may be preferable.

NSCLC that involves the SVC frequently invades at or near the caval-azygos vein junction (Fig. 2). Depending on their location, they may also involve the truncus anterior branch of the right pulmonary artery, the right phrenic nerve, and the right mainstem or upper lobe bronchus. The tissue planes are often lost between the tumor and the wall of the SVC secondary to the desmoplastic tumor response as well as the reaction from induction therapy. One should avoid the temptation to dissect the tumor from the SVC as troublesome bleeding can occur in the absence of appropriate initial vascular control maneuvers. If palpation of the tumor suggests involvement of the SVC, then no further dissection in that area should be performed. Efforts should now be made to obtain proximal control of the SVC, to dissect and control the left innominate vein, and to identify whether the phrenic nerve can be preserved. The superior pulmonary vein is rarely involved by the tumor and, provided there are no intraoperative discoveries that preclude an attempted R0 resection, division of this vessel is a logical first maneuver. This provides exposure to the proximal right pulmonary artery and associated truncus arteriosus. If the tumor involves the pulmonary artery in this area, then intrapericardial control of the right pulmonary artery should be obtained between the SVC and the ascending aorta. These maneuvers permit access to the anterolateral aspect of the distal SVC just beneath the azygous vein where vascular control of the distal SVC can now be obtained.

If the tumor invades the SVC on its lateral wall only, it may be possible to place a partial occlusion clamp in anticipation of excising a portion of SVC wall (Fig. 3). Before placing any
clamp, it is preferable to mobilize the SVC as much as possible, particularly posteriorly and medially. Division of the azygous vein facilitates the mobilization of the cava. Partial excision of the SVC with either primary or patch closure is typically reserved for tumors that invade less than 50% of the circumference of the SVC. If a partial occlusion clamp is all that is required, then there is no indication for administration of systemic heparin. The clamp is commonly placed from an inferior to superior direction.

A note of caution is that, after the excision of a portion of the SVC wall, there will be retraction of the edges of the wall of the SVC toward the base of the clamp. If the clamp has not been placed “deep enough” onto the cava, this can make closure of the resulting SVC defect difficult. Therefore, one needs to strongly consider placing umbilical tapes around the SVC proximally and distally except in cases where SVC involvement is minimal and a primary repair can be easily performed.

Once the tumor has been excised and negative margins ensured, a decision needs to be made as to whether to close the defect primarily or with a patch. The amount of SVC excised needs to be quite small before I consider closing it primarily. In the majority of cases a patch of either bovine or autologous pericardium should be used to close the defect (Fig. 4). This avoids narrowing or kinking the SVC with a long primary repair suture line. The surgeon should plan ahead for this and have either harvested autologous pericardium or bovine pericardium on the operative field to mini-
mize the amount of time that the SVC is either partially or completely clamped.

As shown in Fig. 4, a patch is sewn into place using 4-0 Prolene suture. I prefer using bovine pericardium secondary to the ease of handling it, but autologous pericardium is also appropriate to use. Sutures are placed at the superior and inferior aspects of the defect and the patch and then run along the anterior and posterior walls of the defect to close it.

Although it is not always possible to preserve the right phrenic nerve, one should consider this if possible. It can be difficult to identify the phrenic nerve particularly with large tumors invading the cava. If visualized, the nerve can be dissected along the SVC and lifted anteriorly and medially.

**Figure 4** Pericardial patch closure of the SVC defect. Although primary repair of very small caval defects is possible, most defects require an autologous or bovine pericardial patch to avoid narrowing of the SVC luminal diameter. SVC = superior vena cava; v. = vein.
Figure 5  Completed SVC patch closure with phrenic nerve preservation. It is not always possible to preserve the phrenic nerve, but when possible, this should be performed. Division of the azygos vein facilitates exposure to the distal SVC and the subsequent placement of vascular clamps. n. = nerve; SVC = superior vena cava.
away from the defect that needs repair (Fig. 5). If, however, the phrenic nerve is involved, then there should be no hesitation to resect it en bloc with the specimen to achieve a complete resection. Attempts to dissect the phrenic nerve without proximal and distal control of the SVC as well as the left innominate vein may result in bleeding. Therefore, under these circumstances it is wise to resect the nerve en bloc with the tumor and SVC.

When the tumor involves more than 50% of the SVC circumference (Fig. 6), that portion of cava should be resected and reconstructed with either a polytetrafluoroethylene (PTFE) graft or an autologous or bovine pericardial tube. There are some risks associated with using a PTFE graft for SVC reconstruction, including the need for postoperative anticoagulation, risk of infection, and thrombosis. Often the amount of autologous pericardium may be insufficient to construct a long tube. Spaggiari and coworkers have recently advocated the used of a bovine pericardial prosthesis. An alternative that is appealing is the use of cryopreserved arterial allografts as described by Martorell and coworkers. A downside to using these allografts is that various sizes need to be available and their cost is not trivial. However, their relative resistant to infection, the ease of handling this tissue, and no need for anticoagulation make their use attractive, particularly when a concomitant lung resection is performed.

Following administration of 5000 units of intravenous heparin, the proximal and distal cava are clamped and the cava is resected (Fig. 7A). In anticipation of clamping and resecting the SVC, the patient’s bed should be placed in reverse Trendelenburg position. The patient’s blood pressure should be maintained with volume expansion through the previously placed groin line and vasopressors should be used as needed. Although the use of SVC shunts has been described, I have never used one, as nearly all these reconstructions should be achievable with a well-tolerated 30 to 60 minutes of complete SVC occlusion. Postoperatively, it is not uncommon for patients to have some swelling and cyanosis of the head and neck as well as some conjunctival petechiae; all this typically resolves in a few days.

The graft of choice is brought onto the operative field. The distal anastomosis is performed first using a 4-0 Prolene suture (Fig. 7B). This distal anastomosis is then tested for evidence of a significant leak that may require a repair suture. The distal anastomosis is then performed. Before tying the distal suture line, the graft is deaired and then the knot is secured. Again, the surgeon needs to ensure that there is an adequate length of proximal and distal SVC from the clamps.
Figure 7 Complete SVC resection and reconstruction. (A) Following resection of the SVC, the operator needs to ensure that the proximal and distal margins are histologically free of malignancy. In general, there is no need to reconstruct the left innominate vein provided there are adequate collaterals. (B) Given that the transected edges of the cava will retract toward the base of the clamps, one needs to ensure that there are ample cuffs of caval wall to sew in the graft. The proximal portion of the graft is typically sewn in first. SVC = superior vena cava; v. = vein.

Figure 8 Less common reconstructive techniques to re-establish upper body venous contiguity. (A) Occasionally the right subclavian and jugular venous systems are either occluded or surgically absent. Under these circumstances the distal SVC is reconstructed to the left innominate vein. (B) Under very rare circumstances (described in the text), the operator may need to reconstruct both the right and the left innominate venous systems. SVC = superior vena cava; v. = vein.
to sew the graft in place. It is imperative that there be no
tension on the graft. An equally poor result is graft redu-
dancy (particularly if a bovine or autologous pericardial graft 
is used), which could result in torsion or kinking of the graft.

Although the most common reconstruction following SVC 
resection is for the distal graft to be anastomosed to the right 
nominate vein, there are circumstances where the graft may 
need to be placed to the left innominate vein (Fig. 8A). These 
include clot or occlusion of the right jugular venous system 
or surgical excision of these veins from a prior head and neck 
procedure. The proximal anastamosis can be performed ei-
ther from the transected proximal SVC or directly from the 
right atrial appendage. If the atrial appendage is used, then a 
Statinsky clamp on the atrium is used for vascular control 
while the anastomosis is created.

In the very rare situation where the left jugular venous 
system is either clotted or surgically removed, one needs to 
consider revascularizing the left subclavian vein via the left 
innominate vein graft as well as an additional graft to the right 
innominate vein to facilitate head and neck venous drainage. 
This is depicted in Fig. 8B. It is preferable to avoid graft-to-
graft anastomoses in this low-flow system. This helps avoid 
potential clotting and occlusion of one graft that could result 
in propagation of clot into the other graft with the end result 
being the occlusion of both.

Discussion

The results of 109 patients undergoing SVC resection for 
lung cancer involvement over a 35-year period have been 
highlighted by Spaggiari and coworkers. In this retrospec-
tive study, 50% of patients had a pneumonectomy with 40% 
of these patients having a carinal pneumonectomy. Using a 

multivariate analysis, the risk of major postoperative compli-
cations correlated with the use of induction therapy. Factors 
associated with an increased risk of death using this analysis 
include the need for pneumonectomy and complete replace-
ment of the SVC with a prosthetic conduit.

In conclusion, for appropriately selected patients SVC re-
section and reconstruction is a safe and effective procedure to 
achieve a R0 resection for T4 lung cancers invading the SVC. 
Preoperative staging and choice of incision are important 
aspects to consider before approaching these tumors. The 
majority of these patients can be managed with a partial caval 
wall resection and patch reconstruction. In these patients I 
initiate aspirin therapy immediately postoperatively and con-
tinue it for 3 months. If a PTFE conduit is required, then I 
have empirically instituted Coumadin for 3 to 6 months post-
operatively. More recently, we have used a cryopreserved 
arterial allograft or a bovine pericardial tube to avoid the need 
for postoperative Coumadin therapy in those patients who 
require a SVC resection and reconstruction.

References

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