end-diastolic diameter was improved in 5 patients; right ventricular size and function improved in 3 patients. Three late deaths due to carcinoid progression occurred postoperatively at 39, 5, and 30 months.

DISCUSSION

Previous studies have shown that tricuspid and pulmonary valve replacement can improve symptoms and survival in patients with right heart failure due to carcinoid heart disease.¹ Improved functional status and cardiac chamber size were also noted in our carcinoid patients with 4 valve replacements. Notably, a PFO was present in only 3 patients, and each was detected only by intraoperative transthoracic echocardiography with saline injection. Thus, our experience documents that an intracardiac shunt is not necessary for development of left-sided carcinoid valve disease, despite other reports.^{4,5}

CONCLUSIONS

Although carcinoid heart disease with involvement of all 4 valves is rare, we conclude that quadruple valve replacement in symptomatic patients is a reasonable option that can result in functional improvement with acceptable risks.

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Successful resection of localized pulmonary mucormycosis after bone marrow transplantation using a virtual 3-dimensional pulmonary model on a personal computer

Hideyuki Maeda, MD, Masato Kanzaki, MD, Tamami Isaka, MD, PhD, and Takamasa Onuki, MD, PhD, Tokyo, Japan

Mucormycosis is a rare and fatal infectious disease. Pulmonary mucormycosis most often occurs in patients with neutropenia, immune deficiencies, malignant disease, malnutrition, diabetes, and trauma, as well as in patients undergoing organ transplantation or chelation therapy involving deferoxamine.^{1,2} For control of the underlying disease, a polyene administration and surgical resection of infected lung segments may prove helpful. We report a case of localized pulmonary mucormycosis after bone marrow transplantation that was successfully resected using a virtual 3-dimensional pulmonary model on a personal computer.

CLINICAL SUMMARY

A 28-year-old man, treated with allogeneic bone marrow transplantation for acute lymphatic leukemia in March 2009, had progressive dyspnea and productive cough in May 2009. Chest radiography and computed tomography (CT) revealed a fungus ball in the left upper lobe of the lung (Figure 1, A). *Mucor* was detected by bronchoscopic biopsy. When liposomal amphotericin B (L-AMB) was administered, the size of the fungus ball reduced immediately (Figure 1, B). However, because the patient became resistant to L-AMB, he was referred to our division for surgery for pulmonary mucormycosis. Preoperative blood chemistry analysis showed pancytopenia and renal insufficiency (the serum creatinine level 1.94 mg/dL) caused by ongoing L-AMB administration. Chest CT demonstrated an 18-mm cavitary mass in S1+2c of the left lung. For preoperative simulation of surgical resection, we used free software application such as CTTRY, where we could mark on pulmonary arteries, veins, bronchi, and fungus ball of the images on high-resolution CT images. With 60 2-mm high-resolution CT images of the fungus ball and hilum, in DICOM (Digital Imaging and Communications in Medicine) format, we obtained 3-dimensional images for a patient

From the Department of Surgery I, Tokyo Women's Medical University, Tokyo, Japan.

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Address for reprints: Masato Kanzaki, MD, Department of Surgery I, Tokyo Women's Medical University, 8-1 Kawada-cho, Shinjuku-ku, Tokyo 162-8666, Japan (E-mail: kanzaki@chi.twmu.ac.jp).

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FIGURE 1. A, A computed tomogram (CT) shows a fungus ball in the S1+2 of the left upper lobe of the lung. B, The size of a fungus ball was decreased by administering liposomal amphotericin B (L-AMB) before the operation. C, Three-dimensional images of the left lung based on high-resolution CT with 2-mm CT slices. Pulmonary arteries, veins, and bronchi are shown in red, blue, and yellow. A fungus ball was located in S1+2 of the left lung. D and E, Comparison of 3-dimensional images and intraoperative findings. T, Tumor; PA, interlobar pulmonary artery; ★, lingular segmental pulmonary artery (A4+5); ★★, apicoposterior segmental branch (A1+2c); LUL, left upper lobe; LLL, left lower lobe.

using Metasequoia shareware (Figure 1, C). We planned the operation based on the 3-dimensional image; 3 subsegments (ie, S1+2c, S3a, and S4a) needed to be resected to remove the fungus ball completely. Video-assisted thoracoscopic surgical resection of the subsegments was performed (Figure 1, D and E). Macroscopic examination of the surgical specimen revealed a 20-mm left upper lobe fungus ball cavity (Figure 2, A). Microscopically, a Grocott stain highlighted the fungal structures (Figure 2, B). The patient's

postoperative course was uneventful. He was discharged on postoperative day 9. He is active without respiratory limitation.

COMMENT

Successful treatment of mucormycosis consists of early diagnosis, correction of underlying risk factors, performing surgical resection, and prompt antifungal therapy. It is difficult to diagnose pulmonary mucormycosis, because chest

FIGURE 2. A, Macroscopic findings. The size of the mass is 20 mm. A fungus ball is present inside the mass (white arrow). B, Photomicrograph of the lesion shows characteristic broad, aseptate hyphae with stubby, right-angled, fingerlike branches in a background of necrotic tissue (Grocott's methenamine silver stain, original magnification $\times 200$).

radiographic findings are variable, culture results are commonly negative, and there are currently no routinely available serum immunologic assays for it. Pulmonary mucormycosis is usually diagnosed by histopathology. Transbronchial biopsy procedures or a surgical lung biopsy procedure may be required to obtain an adequate specimen for diagnosis. Generally, a polyene, such as the AMB or L-AMB, is administered as primary antifungal therapy. However, blood vessel thrombosis and resulting tissue necrosis during mucormycosis can result in poor penetration of antifungal agents to the site of infection. Therefore, surgical debridement of necrotic tissues may be critical for complete eradication of mucormycosis.³ Roden and associates⁴ reported that the mortality rate of pulmonary mucormycosis is 76% (170/220 patients). However the patients who underwent surgical resection were significantly more likely to survive than those who did not.⁴

In this case, although the patient's pulmonary mucormycosis had been controlled and localized by administering L-AMB, surgical resection was selected. We prefer segmentectomy or more conservative resection to lobectomy for peripheral, small, stage I non-small cell lung cancer. Therefore, we performed multi-subsegmentectomy for the localized pulmonary mucormycosis. Because we constantly focus on the possibility of lung-saving procedures, we attempted to reconstruct using anatomically correct images

with a freeware program. After the images had been uploaded to a personal computer, the pulmonary arteries, pulmonary veins, and bronchi were traced in the images. The location and thickness of the bronchi and pulmonary vasculature were rendered as different-sized cylinders. Next, on the basis of the resulting numerical data, 3-dimensional images were reconstructed. The reconstructed images can be manipulated by virtual surgical procedures such as reshaping, cutting, and moving.⁵

Although the incidence of mucormycosis is increasing, surgical excision of localized disease appears to be the most reliable method of treating pulmonary mucormycosis.

In conclusion, early detection and aggressive treatment for pulmonary mucormycosis offer the best chance of patient survival.

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