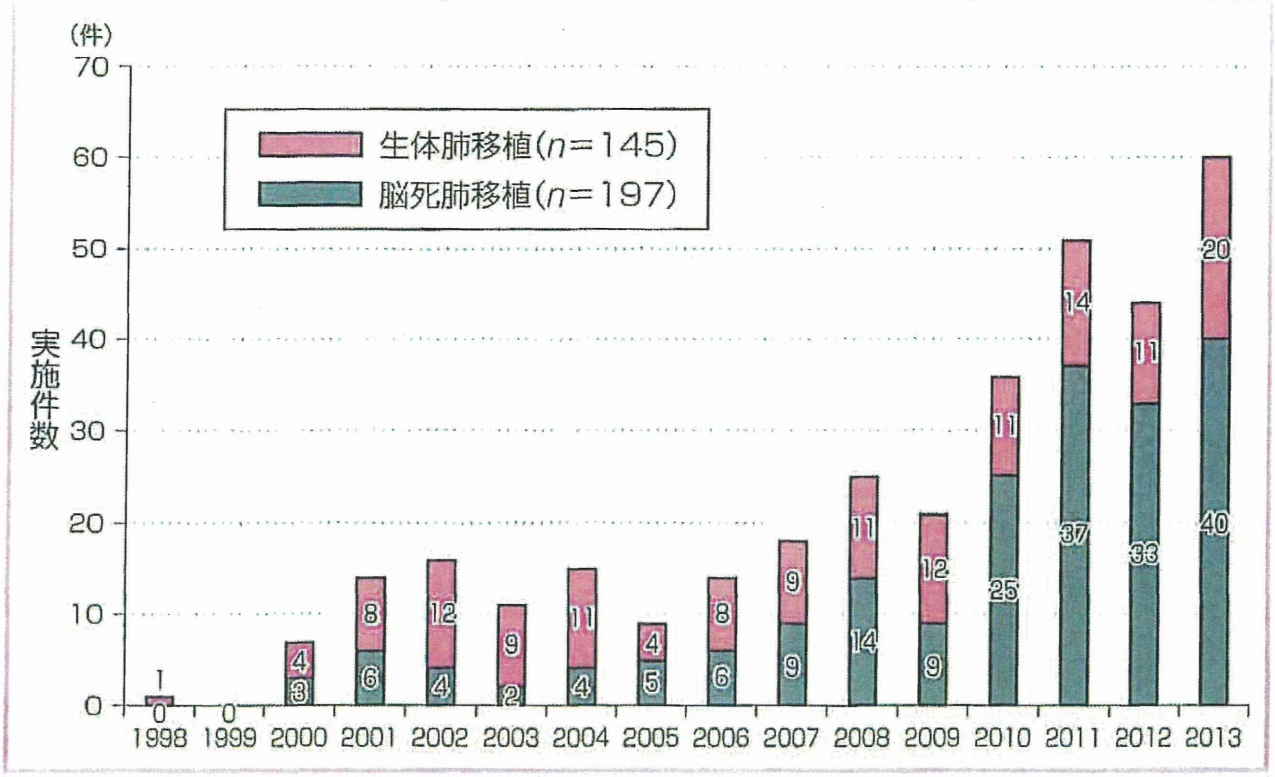

図 5　わが国における脳死・生体肺移植の実施件数の年次推移

[日本肺および心肺移植研究会ホームページ：レジストリーレポート．〈http://www2.idac.tohoku.ac.jp/dep/surg/shinpai/pg185.html〉(2014/6) を改変して引用]

で実施された生体肺移植となった．脳死肺移植は約 1 年半遅れて，2000 年 3 月に東北大学病院と大阪大学医学部附属病院で，それぞれ右片肺移植と左片肺移植が実施された[9, 10]．

b. わが国の肺移植の実施実績は？

1998 年の生体肺移植と 2000 年の脳死肺移植によって日本の肺移植医療がスタートしたものの，2010 年 7 月に臓器移植法が改正されるまでは，生体肺移植スタート以来約 12 年間で 95 件（年平均 7.9 件）であったのに対して，脳死肺移植は約 10 年間で 66 件（年平均 6.6 件）ときわめて限定された実施数に留まっていたのみならず，脳死肺移植の実施数が伸び悩む中で，生体肺移植の実施数が先行するという，ある意味いびつな状況になっていた．2010 年 7 月の臓器移植法の改正の後は，2013 年 12 月までに実施された生体肺移植が 3 年 5 ヵ月で 50 件（年平均 14.6 件）と増加したものの，脳死肺移植数は 119 件（年平均 38.3 件）と生体肺移植を大きく上回ることになった（**図 5**）[11]．

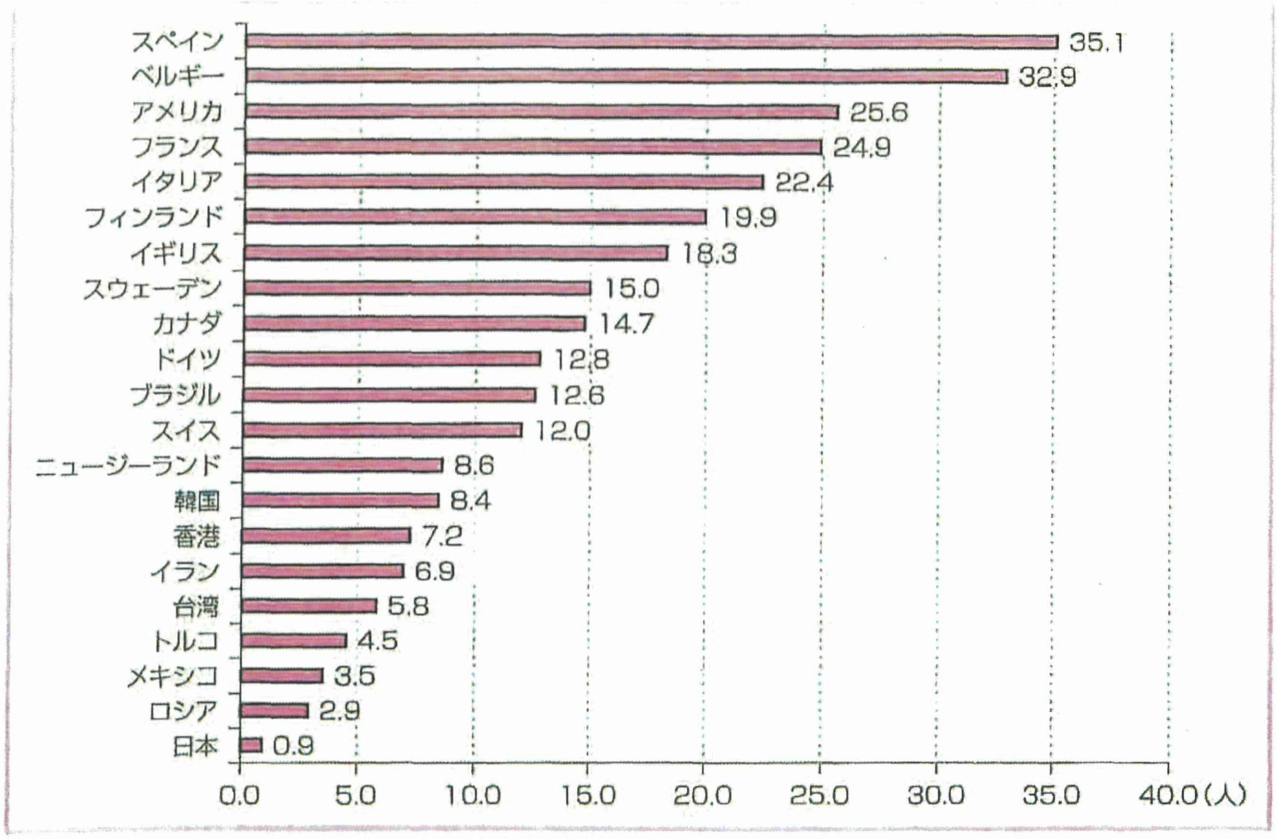

図6　人口100万人あたりの脳死下臓器提供数

[International Registry in Organ Donation and Transplantation ホームページ：2012年の集計データ．〈www.irodat.org〉(2014/6) より引用]

これは，取りも直さず脳死下での臓器提供が改正臓器移植法の施行に伴って年間約7件から40件ほどに増加したことによるものである．ただ，この数字は国際臓器提供・臓器移植レジストリーによれば人口100万人あたり0.9と，欧米に比較すれば1/20以下という，いまだにきわめて限られた数となっている（**図6**）．

c. わが国の肺移植の成績は？

わが国の肺移植の実態については，日本肺および心肺移植研究会のホームページで年次報告として公開されている[11]とともに，日本移植学会の機関誌にも毎年報告されている[12]．肺移植はここ数年，年間脳死肺移植が30～40件前後，生体肺移植が十数件実施されているため，さまざまなデータは日々変わっていくが，移植後の予後についてはここしばらく大きな変動はなく，2014年のレポート（2013年末までに実施された脳死肺移植197件，生体肺移植145件）によれば，5年生存率

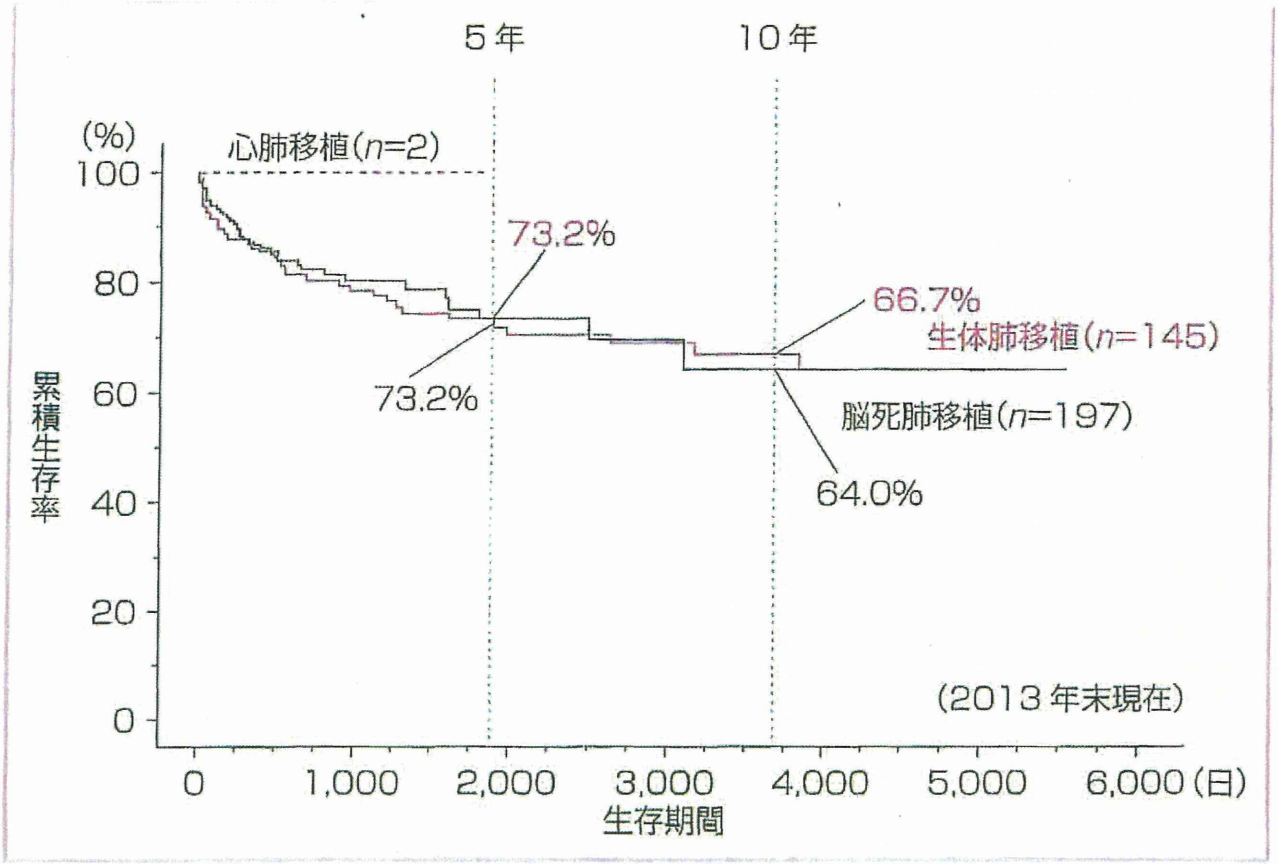

図7　わが国の脳死・生体肺移植の移植後生存率
[日本肺および心肺移植研究会ホームページ〈http://www2.idac.tohoku.ac.jp/dep/surg/shinpai/index.html〉(2014/6) より引用]

70%台，10年生存率60%台という優秀な成績を上げている（**図7**）[11]．心肺移植は，これまで大阪大学医学部附属病院での実施例2例のみであるが，2013年末現在，両者とも健在である．

肺移植の術式には脳死肺移植と生体肺移植があり，脳死肺移植はさらに両肺移植と右または左片肺移植に，生体肺移植は両側生体肺葉移植と片側生体肺葉移植に分けられる．このような術式は，レシピエントの疾患や肺の状態，レシピエントとドナーの体格のマッチングなどを考慮して決められるが，詳しくは別の章にまとめる（第Ⅱ・Ⅲ章参照）．このような術式別の予後をみると，片側生体肺葉移植の成績がやや劣るが，その他の3術式はほぼ同じ成績を上げている（**図8**）[11]．

肺移植では，数多くの適応疾患があるが，2014年2月末まで実施された脳死肺移植205例の中で10例以上の実施実績のある6疾患，気管支拡張症（BE）14例，閉塞性細気管支炎（BO）15例，慢性肺気腫

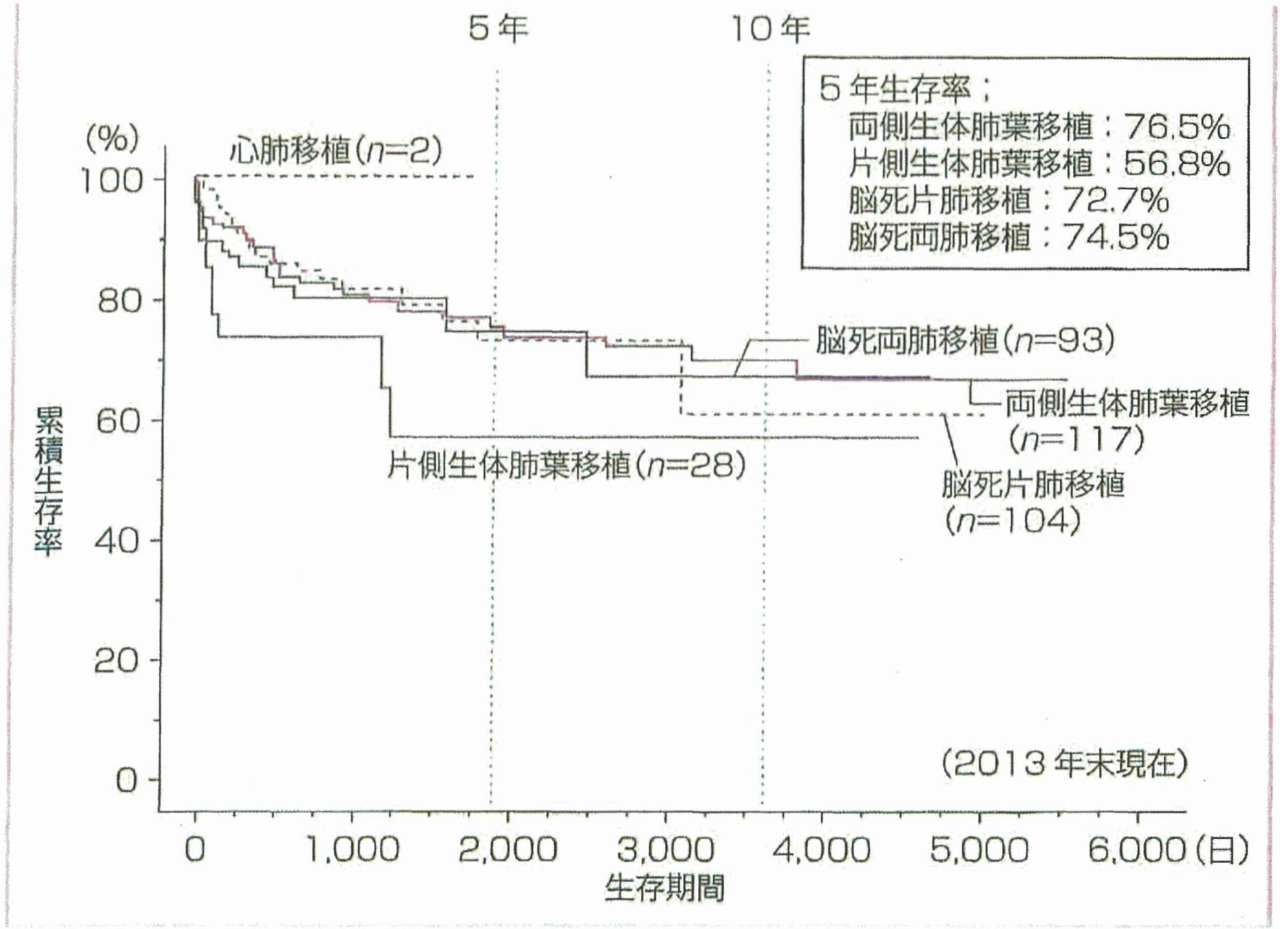

図8　わが国の術式別肺移植後生存率

[日本肺および心肺移植研究会ホームページ〈http://www2.idac.tohoku.ac.jp/dep/surg/shinpai/index.html〉(2014/6) より引用]

(emphysema) 15例，肺線維症と間質性肺炎 (IPs) 43例，肺リンパ脈管筋腫症 (LAM) 62例，肺動脈性肺高血圧症 (PAH) 28例について疾患別生存率をみると，気管支拡張症はまだ5年経過した例がなく3年生存率は77%であり，他の疾患については5年生存率で閉塞性細気管支炎70%，慢性肺気腫92%，肺線維症と間質性肺炎73%，肺リンパ脈管筋腫症72%，肺動脈性肺高血圧症78%と，疾患によって若干の違いがみられるものの，統計学的に有意な差はみられていない (**図9**)．疾患別の予後については，肺以外の全身の病態や，片肺移植における非移植側疾患肺に起因する合併症など，さまざまな移植肺以外の因子による影響も念頭に置かなくてはならず，単純には解釈できないむずかしさもある．

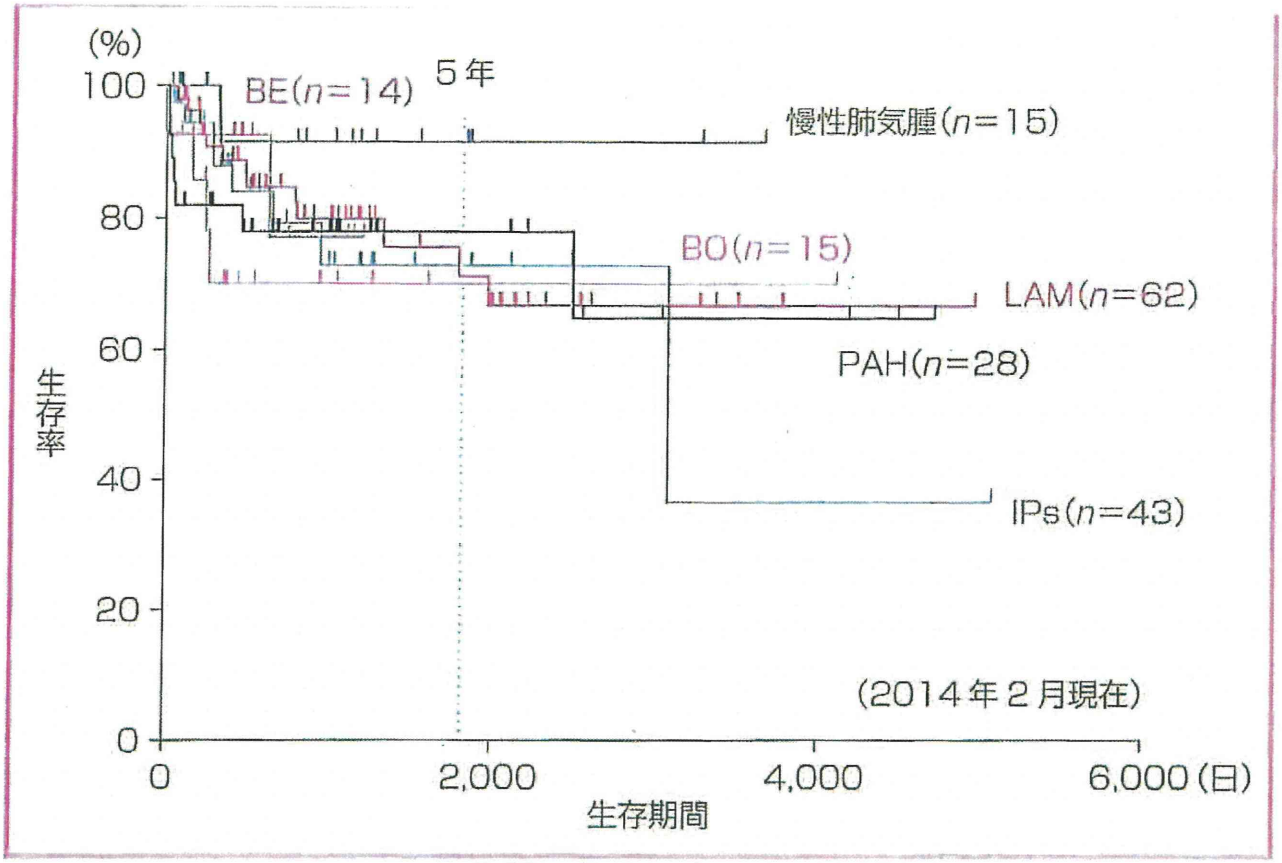

図9　わが国の主たる原因疾患別脳死肺移植後生存率

d. 脳死ドナーからの肺の提供はむずかしい？

脳死下での臓器提供数が限られる中，日本では貴重な臓器提供の意志を最大限活かそうと，メディカルコンサルタントという仕組みを導入した．平たく言えば，脳死下での全身管理をサポートして臓器移植の効率を改善しようとするとともに，適切な情報を移植実施施設に提供することで，無駄な摘出のための出動を削減しようというのが主な目的である．このような体制の整備もあったためか，日本での脳死ドナーからの肺の提供率はきわめて高い．米国 UNOS（United Network for Organ Sharing）の 2012 年のレポート[13]によれば，脳死臓器提供数に対する実施肺移植数の比率は 0.39 と報告されているが，わが国の 2011 年の実績では年間提供件数 44 件に対して肺移植実施数は 37 件であり，提供数に対する比率は 84％にものぼる．

脳死となった原因にもよるであろうが，国際登録における臓器提供者の年齢分布では，最近 50 歳代以上からの提供の比率が増えてきているとはいうものの，30 歳代までの提供が 5 割を超えている[7]のに比して，

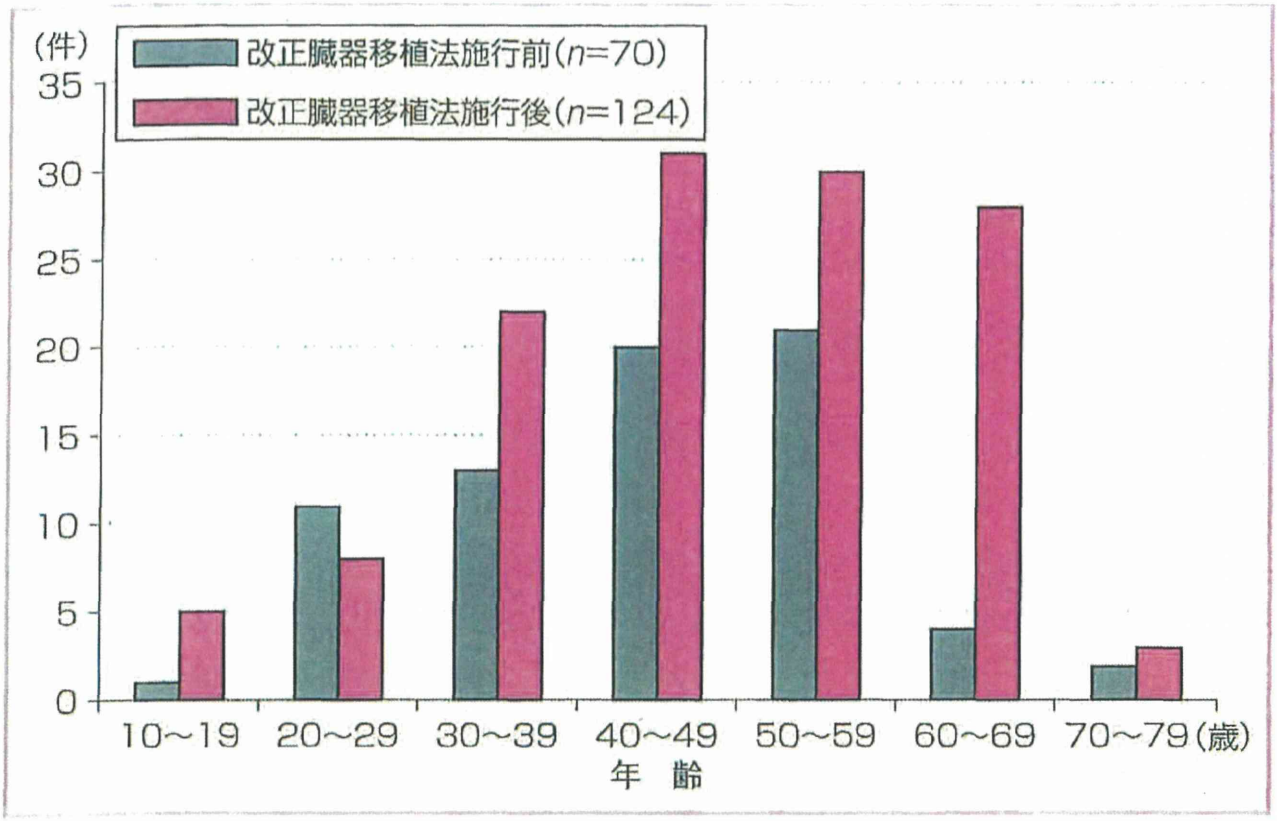

図 10 わが国の脳死下での臓器提供で，年齢情報が公開されている 194 件の年齢分布

［日本臓器移植ネットワークホームページ．〈http://www.jotnw.or.jp/〉（2014/7）より引用］

日本では提供者の年齢としては 50 歳代がもっとも頻度が高く，改正臓器移植法施行後提供数の増加がもっとも著しいのが 60 歳代であることを考えると（**図 10**），肺移植の実施率の高さは驚愕に値するといっても過言ではない．

脳死下では，自発呼吸の消失や循環維持のための管理のむずかしさなども相まって，肺を良好なコンディションに維持することがむずかしいといわれていたが，綿密な管理を行えば肺移植の実施率を高くすることも十分可能であることが日本の経験によって示されたといえる．

e. 将来への課題は？

数少ないながらも 10 年以上の経験を積み重ねて，肺移植の領域でもいくつかの問題点が指摘されてきている．現在検討の対象となっていることは 2 件で，1 件は待機患者の疾患別予後の違いによる肺移植機会の不平等，もう 1 件は合致する条件のレシピエント候補がみつからない場

合における提供肺の有効利用である．後者については，サイズマッチングが問題の場合や提供肺が部分的にしか移植に適さないと判断する場合に，小児への部分肺葉移植を念頭に置いた，マッチングの条件を外した候補者の再確認を厚生労働省に要望として提出し，2014年よりレシピエント選択条件に組み入れられることとなった．一方，前者については，間質性肺炎（肺線維症）や気管支拡張症など待機リスト上で生存期間が他疾患に比して明らかに短いものについて，待機期間の一律上乗せをし，疾患別の肺移植の機会をより均等なものにするとともに，待機リスト上での死亡率を低下させようというものであるが，これについては議論が継続中である．

移植成績という点では，わが国の肺癌の外科治療における臨床病期ＩＢ期の手術成績をも凌ぐ実績を上げてはきたという点では，医療としての基盤を確実なものにしたといってよいと思われるが，一方で，同じ臓器移植でも心臓移植の成績（1年生存率98%，5年生存率96%）に比べると見劣りがすることは否めない．その原因の1つとして，移植直後より移植肺が機能しない，いわゆる移植肺機能不全が挙げられる．肺移植実施後30日以上を経過した183例のうち，術後30日以内に死亡したのは6例（3.3%），また，3ヵ月以内に死亡したのは12例（6.6%）と，術後急性期の成績の改善が全体の成績の改善にとって重要であることが分かる．移植肺機能不全の最大の要因と目される，移植肺の虚血再灌流障害を有効に制御・克服する手段の開発が今後の課題といえる．

CHAPTER ?

Open Hepatic Left Lateral Sectionectomy for Live Donor Transplantation

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Toshiya Kamiyama, MD

Satoru Todo, MD, FACS

INTRODUCTION

The left lateral segment is frequently used in a living donor liver transplantation for pediatric recipients. For this purpose, open hepatic left lateral sectionectomy is selected for the donor, and the laparoscope-assisted method is an alternative. The decision to do an open or a laparoscopic approach should be made bearing the principle of "donor safety first" in mind.

ACS Multimedia Atlas of Surgery: Liver Surgery Volume

In addition to a general medical work-up, an evaluation of the liver is mandatory prior to the operation. Information about the anatomy of the three major vessels (hepatic artery, portal and hepatic veins) is inevitable and can clearly be depicted by enhanced 3-phase computed tomography and/or its 3-D reconstruction. In particular, the left lateral segment of the liver occasionally has anatomical variations of the artery. For example, an accessory left hepatic artery branches off from the left gastric artery in 10-15% of all cases. The normal branch pattern of the left hepatic artery is shown in Figure 1, and an anatomical variation of the left hepatic artery off of the left gastric artery in Figure 2.

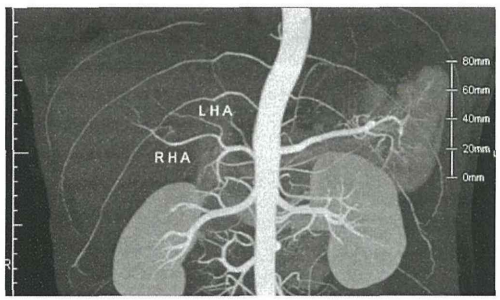

Figure 1: The left lateral segment of the liver occasionally has anatomical variations of the artery. The normal branch pattern of the left hepatic artery is shown (anterioposterior view).

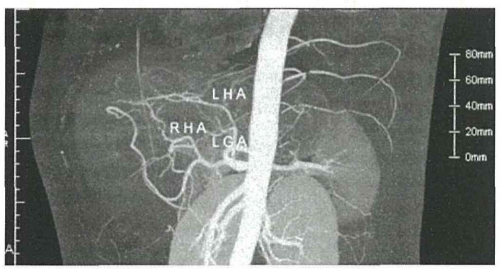

Figure 2: An anatomical variation of the left hepatic artery off of the left gastric artery is seen in 10-15% of all cases. Figure 2 depicts this most common anatomical variation (anterioposterior view).

STEP 1: LAPAROTOMY, LIVER BIOPSY, CHOLECYSTECTOMY, AND INTRAOPERATIVE CHOLANGIOGRAPHY

Under bilateral subcostal and upper midline incision (Mercedes incision), the abdominal cavity is explored. Macroscopic examination followed by wedge biopsy of the liver is performed to confirm eligibility for a donor. Cholecystectomy is carried out in the usual manner, and an intraoperative cholangiogram is obtained through a catheter inserted into the cystic duct. Because the left hepatic duct is retrieved with

a left lateral segment graft, knowledge of the precise biliary anatomy is necessary to make a decision on the cut-line. Commonly, the left hepatic duct is transected just to the left side of the bifurcation. In one variation, the bile duct for a right posterior segment (segments VI and VII) enters into the left hepatic duct in 20% of cases. If this is seen, a cut-line of the left hepatic duct is to be created more left-sided to prevent stenosis on the remnant bile duct of the donor. Many additional anatomical variations also exist in the biliary system. Therefore, extreme caution should be taken. Figures 3 and 4 show an intraoperative cholangiogram illustrating the normal branch pattern of the bile duct.

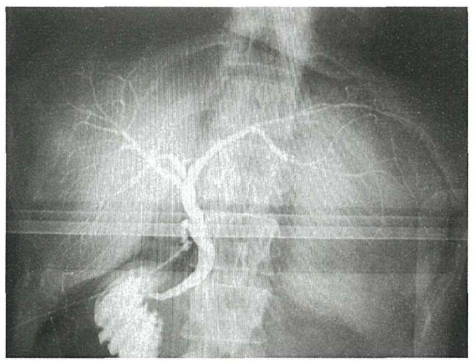

Figure 3: Because the left hepatic duct is retrieved with a left lateral segment graft, precise knowledge of the biliary anatomy is necessary to make a decision on the cut-line. Among the anatomical variations, the bile duct for a right posterior segment (segments VI and VII) enters into the left hepatic duct in 20% of cases.

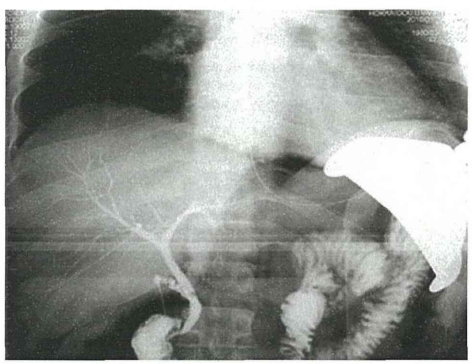

Figure 4: An intraoperative cholangiogram illustrating the normal branch pattern of the bile duct.

Video 1

STEP 2: HILAR DISSECTION (HEPATIC ARTERY DISSECTION)

Hepatic hilar dissection is commenced by the isolation of the left hepatic artery. For this purpose, the left and anterior peritoneum of the hepatoduodenal ligament is peeled off with an electrocautery. Once the anterior wall of the left hepatic artery is identified, further dissection around the artery should proceed, cutting the surrounding tissues such as periarterial nerves and lymphatic ducts in a sharp manner. During this process, excessive dissection should be avoided. Otherwise, the adventitia of the artery might easily be injured. The left hepatic artery should be completely isolated from its origin up to the point entering the liver. Finally, the left hepatic artery is taped with a vessel loop.

When an accessory left hepatic artery is present off of the left gastric artery, the dissection should be started only after the left lateral segment has been mobilized, allowing for a better surgical field. After ligating and dividing the gastric branches from the left gastric artery, the left hepatic artery can be isolated for a longer length than when the normal pattern is observed. In such cases, the length to be dissected is decided considering future anastomosis. Figure 5 shows an isolated left hepatic artery in the normal pattern, and Figure 6 shows an accessory artery off of the left gastric artery.

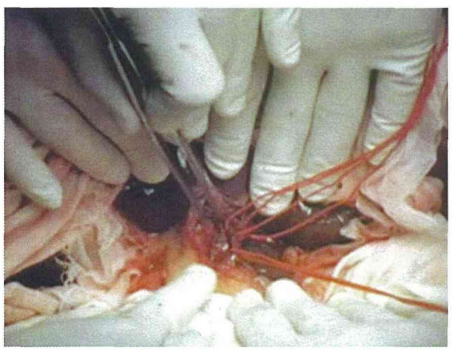

Figure 5: The left hepatic artery should be completely isolated from its origin up to the point entering the liver and taped with a vessel loop.

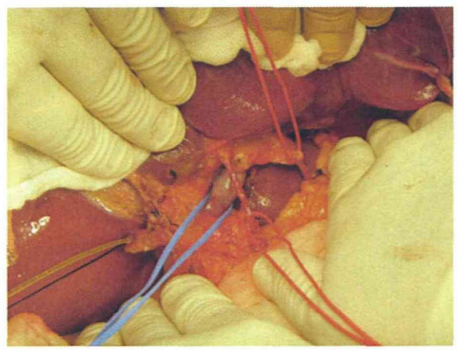

Figure 6: The left hepatic artery should be completely isolated from its origin up to the point entering the liver and taped with a vessel loop.

Video 2

STEP 3: HILAR DISSECTION (PORTAL VEIN DISSECTION)

After finishing the isolation of the left hepatic artery, the dissection of the left portal vein is begun. Behind the left hepatic artery, the anterior wall of the left portal vein can be seen through a blunt division of the surrounding tissues. After ligating and dividing several small portal branches to Spiegel's lobe, the left portal vein can safely be encircled. The dissection should be done completely from the bifurcation up to the point where the Arantius duct (ductus venosus) joins the left portal vein. Finally, the left portal vein is taped with a vessel loop. Figure 7 shows an isolated left portal vein.

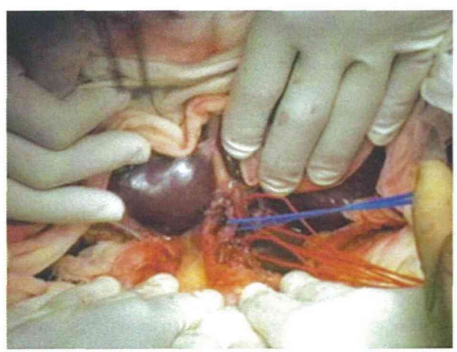

Figure 7: Isolated left portal vein.

Video 3

STEP 4: MOBILIZATION OF LEFT LATERAL SEGMENT

Following the hepatic hilar dissection, the procedure proceeds to the mobilization of the left lateral segment. The falciform, coronary, and left triangular ligaments are dissected mainly with electrocautery. Attention should be paid to the left subphrenic vein during this portion of the operation. To prevent injury to this vein, begin to divide the left triangular ligament on its left side far from the vein, place gauze behind it, and then continue to transect the ligament toward its left-side end. The left-side end should be ligated because a small bile duct may exist inside. Then, divide the ligament toward the right side until the anterior wall of the left hepatic vein is visible. After completing the dissection of all suspensory ligaments, the left lateral segment can be flipped up and mobilized to the right side. Under the mobilization, the lesser omentum and Arantius' duct can be transected. While pulling the upper stump of Arantius' duct cranially, the left and posterior wall of the left hepatic vein can easily be explored. Encircling and taping of the left hepatic vein is possible in 30% of these cases but impossible in the other 70% because of the anatomical character that the confluence of middle and left hepatic veins usually exhibits inside the liver parenchyma. In cases in which the left subphrenic vein enters into the left hepatic vein, the subphrenic vein should be ligated and divided to obtain a sufficient length for the left hepatic vein conduit.

Video 4

STEP 5: INTRAOPERATIVE ULTRASOUND STUDY AND A CUT LINE MARKING

After the hilar dissection and mobilization of the left lateral segment, intraoperative ultrasound study is carried out for the safe parenchymal dissection of the liver. By studying the depicted branches of the hepatic vein and Glissonian pedicles on the cut line, the subsequent procedure can be delineated. Small veins branching off from the left hepatic vein to segment IV, including the paraumbilical vein, occasionally exist, and Glissonian pedicles to segment IV from the umbilical portion are always present on the cut line. Through this type of study, where and how much attention should be paid can be determined. A cut line of the parenchyma is created 1 cm to the right of the falciform ligament and marked with an electrocautery or argon beam coagulator. (Figure 8) The inferior direction of the cut line should be aimed at the left hepatic duct. The use of several hanging sutures is recommended to ease dissection.

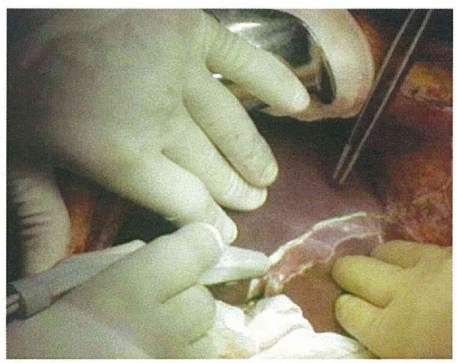

Figure 8: After the hilar dissection and mobilization of the left lateral segment, parenchymal dissection is commenced.

Video 5

STEP 6: PARENCHYMAL DISSECTION

Several techniques and instruments are selected for a parenchymal dissection depending on the surgeon's preference. Combinations of the forceps fracture method, Harmonic scalpel, ultrasound dissector such as Cavitron Ultrasonic Surgical Aspirator (CUSA), bipolar cautery irrigation, and dissecting sealer are commonly used options. In some hospitals, vascular occlusion with Pringle's maneuver is applied during parenchymal dissection. In Video 6, Harmonic scalpel and bipolar cautery irrigation are used without inflow occlusion. Regardless of the techniques or instruments used, vasculature of 2 mm or more in diameter encountered in the dissection should be ligated. Throughout the dissection process, care should be taken to make a cut surface as flat as possible. For the purpose of linear resection, a harmonized tension using hanging sutures may be helpful.

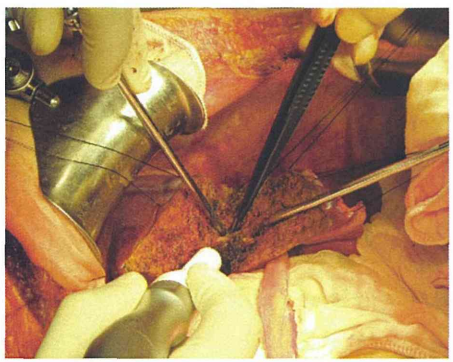

Figure 9

Video 6

STEP 7: BILE DUCT TRANSECTION

During bile duct transection, both the left hepatic artery and left portal vein should be taped together with a vessel loop and retracted in order to prevent injury. After two-thirds of the parenchymal dissection is complete, including the exposure of the left hepatic plate, the plate is encircled by the extra-Glissonian approach. (Figure 7) The plate should be taped with a vessel loop so that it can provide a guide for the following bile duct transection. Under the cholangiogram with an intraoperative fluoroscope, the transection line is determined and clamped, and the plate is cut sharply just to the left of the clamp. Rigorous attention should be paid to avoid any stenosis of the remnant bile duct on the donor. The principle of "donor safety first" may result in two or more bile duct orifices on the graft. This process is the most crucial step of the operation. Anatomical knowledge of the bile duct and the hepatic plate system is critical. Remnant bile ducts and bile ducts on the graft are confirmed with a surgical probe. The bile duct on the donor is then closed by a continuous suture with a 6-0 absorbable monofilament thread. The bile duct on the graft is left open. Bleeding from the bile duct orifices on the graft should be controlled; ischemia should be avoided.

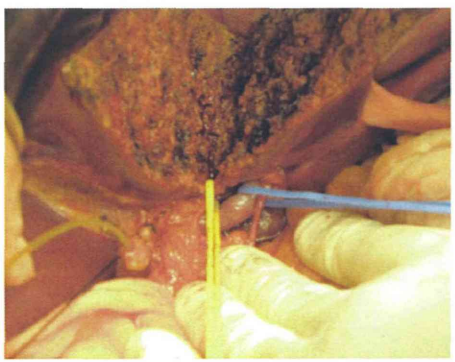

Figure 10: The left hepatic plate is encircled by the extra-Glissonian approach (yellow tape).

Video 7

STEP 8: PARENCHYMAL DISSECTION AFTER THE TRANSECTION OF BILE DUCT AND LEFT HEPATIC VEIN ISOLATION

To make the remaining third of the parenchymal dissection easier and safer, a Nelaton catheter (red rubber catheter) is placed along with the fossa between the left lateral segment and Spiegel's lobe. (Figure 11) By hanging the catheter, the direction to cut becomes much clearer. At the bottom of the dissection, the hepatic plate to Spiegel's lobe should be firmly ligated to prevent biliary leakage. At the end of dissection, the confluence of the middle and left hepatic veins should be clarified, with the left side wall of the middle hepatic vein clearly visible. Finally, the left hepatic vein conduit is isolated for as long as possible. After these procedures, the left lateral segment graft is ready to be excised.

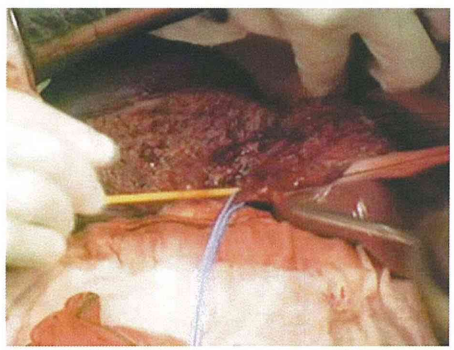

Figure 11: A Nelaton catheter is placed along with the fossa between the left lateral segment and Spiegel's lobe.

Video 8

STEP 9: EXCISION OF THE GRAFT

After double ligature of the proximal end of the left hepatic artery, the artery is transected by placing a small bulldog clip on its distal end. For the transection of the left portal vein, a vascular clamp and a medium-sized bulldog clip are placed on the proximal and distal ends, respectively. Finally, the left hepatic vein is transected by placing a vascular clamp on its confluence, leaving the graft side open. This process is performed without the use of heparin. A left lateral segment graft can then be explanted. Hepatic and portal vein orifices on the donor are closed by a continuous suture with 5-0 and 6-0 non-absorbable monofilament threads, respectively.

Video 9

STEP 10: PARTIAL RESECTION OF SEGMENT IV (OPTIONAL) AND CLOSURE

If segment IV is of too dark a color, partial resection of this segment may be necessary. (Figure 12) Completion of cholangiogram is obtained by an intraoperative fluoroscope to confirm the absence of leakage or stenosis on the remnant bile duct of the donor. (Figure 13) After hemostasis is ensured, the abdominal cavity is irrigated, and a closed drain is inserted adjacent to the cut surface. The purpose of the drain is for monitoring, and the drain usually removed on the first or second postoperative day. The operation is completed by closing the abdominal wall in a layer-by-layer fashion.

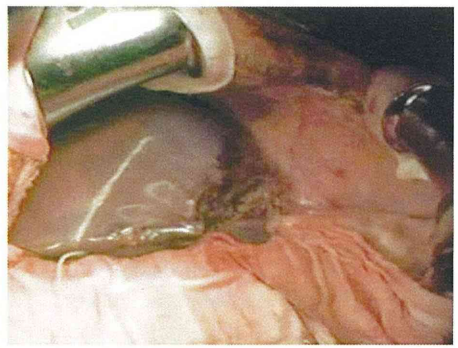

Figure 12

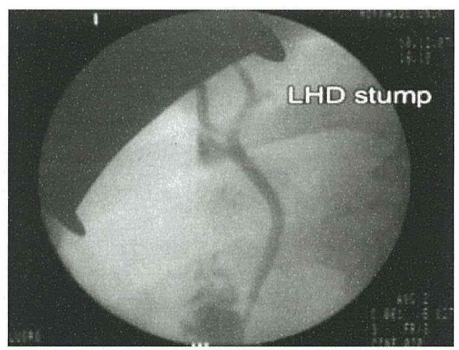

Figure 13

Video 10