大動脈外科の始まり、進展と最近の趨勢

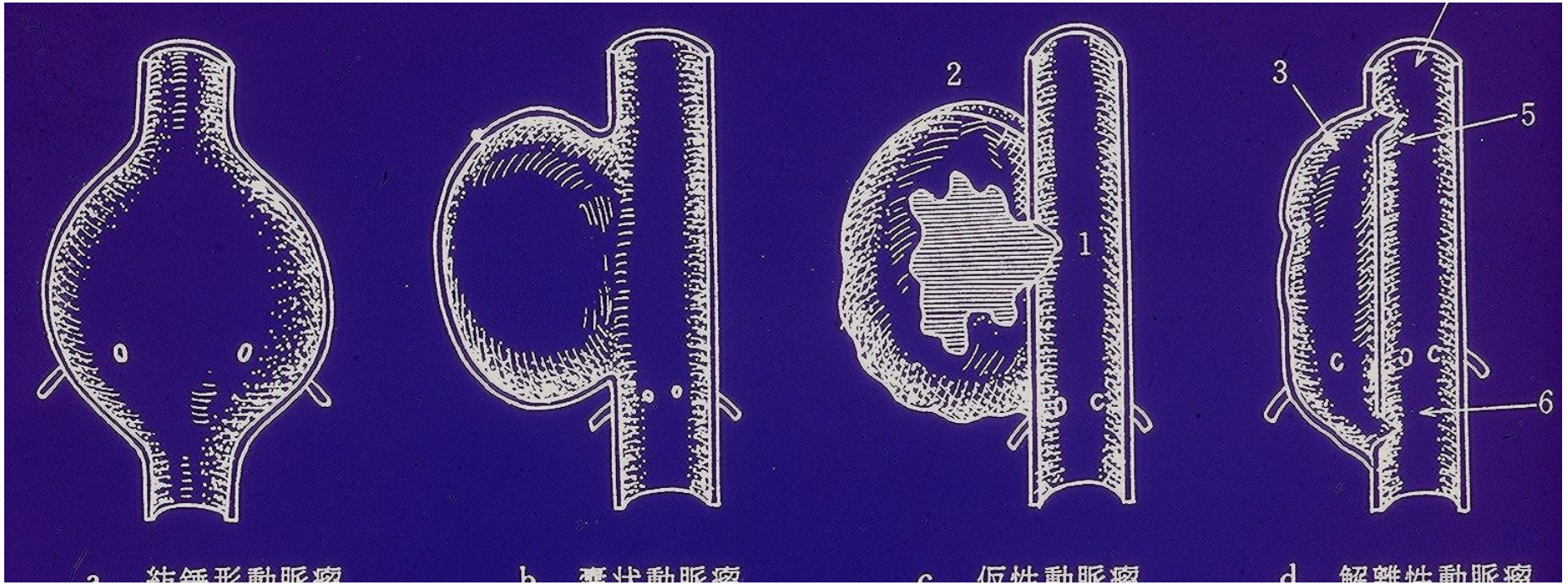
仙台青葉学院大学・仙台青葉学院短期大学
田林　晄一

There is no disease couducive humility
than aneurysm of the aorta

(大動脈瘤ほど扱いにくい病気はない)

(William Osler, 1902)

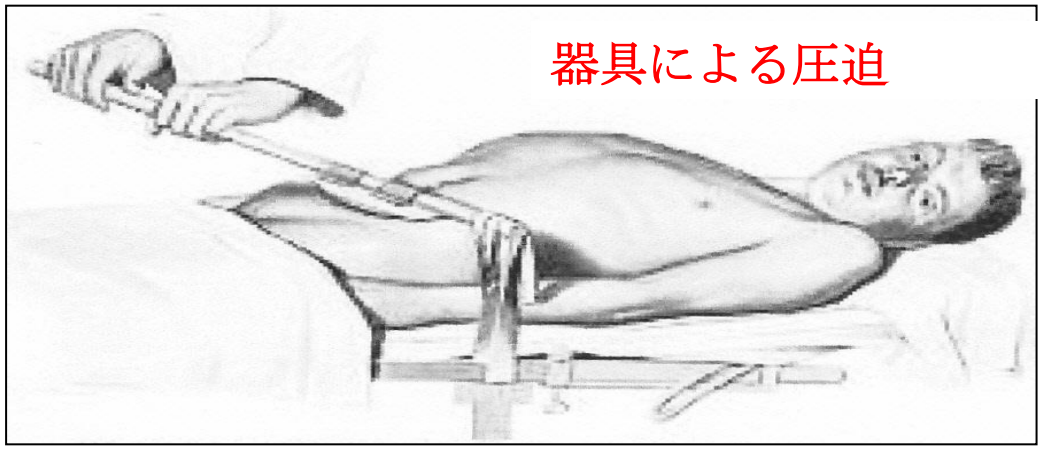
動脈瘤の形状・病態別分類



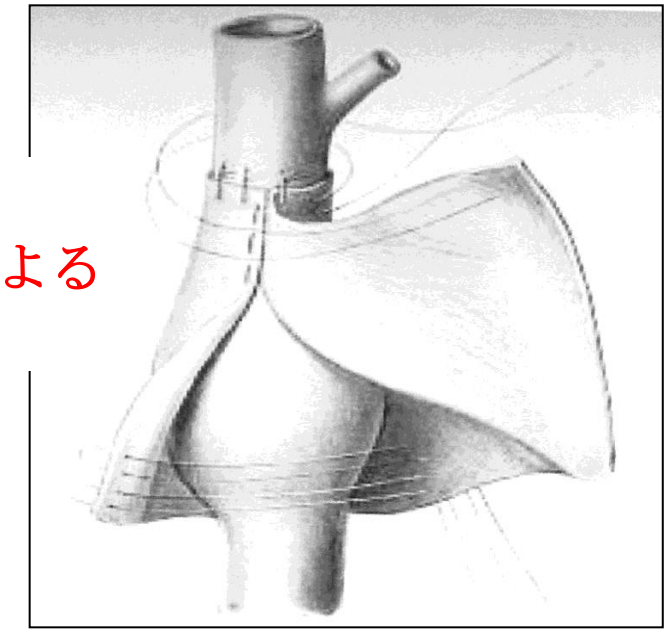
a. 紡錘形動脈瘤　　b. 嚢状動脈瘤　　c. 仮性動脈瘤　　d. 解離性動脈瘤

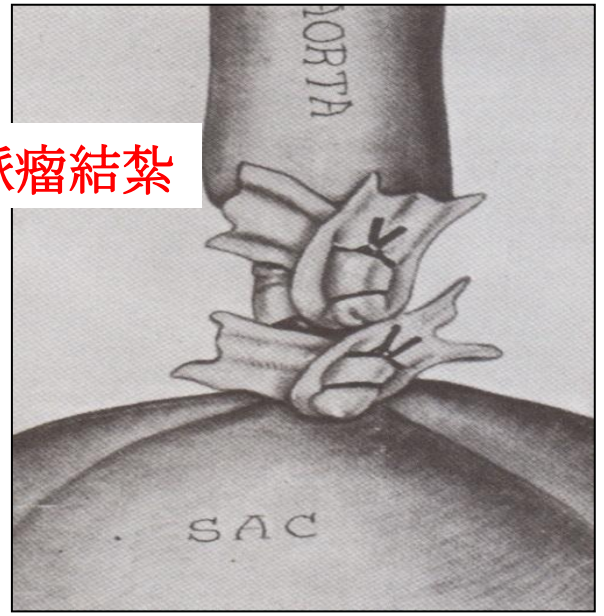
1. 大動脈壁損傷部、2. 血腫、3. 解離腔、4. 真性腔、5. エントリー、6. リエントリー

腹部大動脈瘤治療の苦闘のあゆみ



皮膚、筋膜
セロファンによる
wrapping





大動脈瘤結紮

D.Bergqvist: Historical Aspects on Aneurysmal Sisease
Scandinavian Journal of Surgery 97:90,2008

（田邊達三作成、一部改変）

Albert Einstein

(1879～1955年)

相対性理論、量子論

近代手術法が確立される直前に
腹部大動脈瘤破裂で亡くなった。

1948年に腹部大動脈瘤の前壁をセロファンで
wrappinng する手術を受けた。

その後、数年間は異常はなく過ごした。
1955年の７６歳の時に核兵器廃絶のラッセル・アインシュタイン宣言に署名した２日後に激烈な腹痛を起こし、腹部大動脈瘤の破裂と診断され死亡した。

彼の最後の言葉は
It is tasteless to prolong life artificially.
I have done my share, it is time to go.
I will do it elegantly.

（田邊達三作成、一部改変）

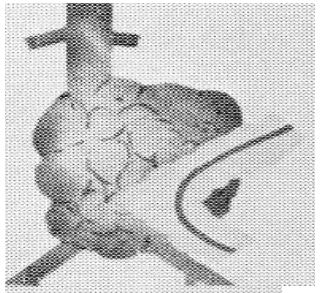
大動脈瘤に対する大動脈置換術の始まり

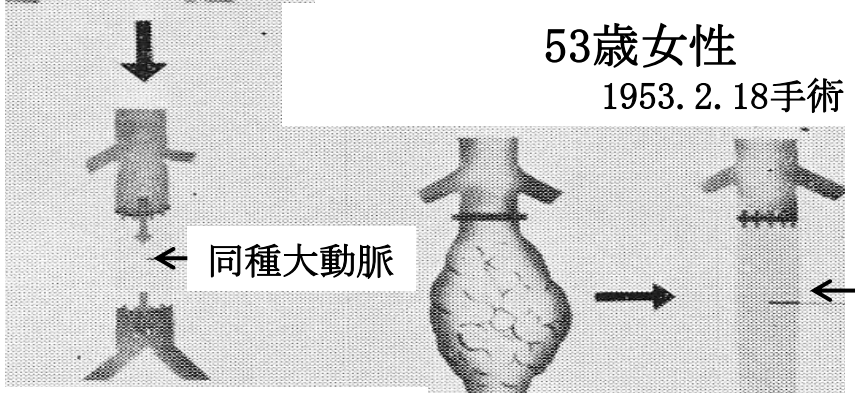
東京大学第２外科
木本誠二教授

50歳　男性
1952.5.25手術

同種、また異種大動脈片移植

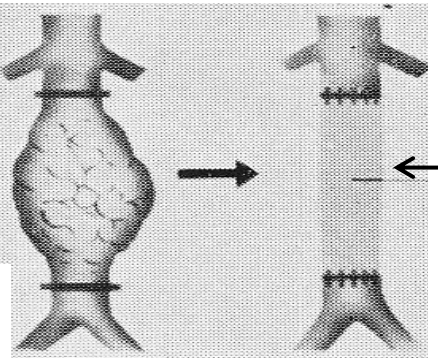
1952 Schafer等：凍結同種大動脈移植
1952 Dubost等:保存同種大動脈移植
1952 木本等:アルコール内保存同種大動脈移植
1953 木本等：アルコール内保存異種（羊）大動脈移植
1953 DeBakey等：同種大動脈移植（7例）





7年半後再発、
人工血管術後死亡

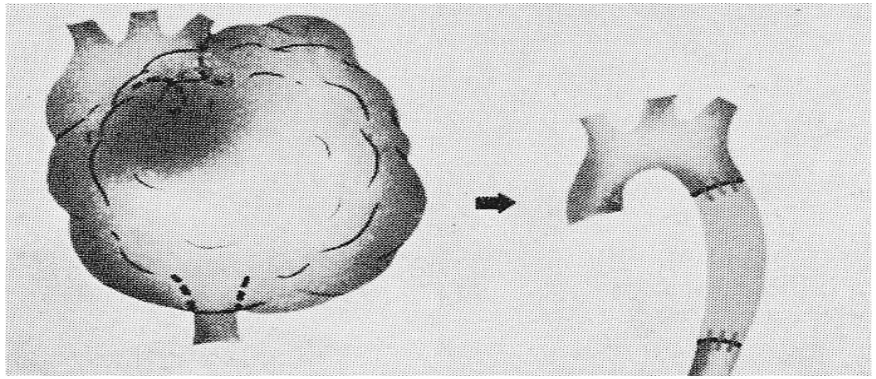
53歳女性
1953.2.18手術



11年後にクモ膜下出血で
死亡、移植片に異常なし

（田邊達三作成、一部改変）

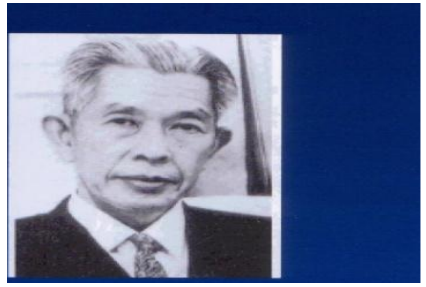
1951　木本等：同種大動脈による
胸部下行大動脈置換（死亡）
1953　DeBakey:同種大動脈による
胸部下行大動脈置換（生存）
55歳、男性（1951.7.5手術）



巨大な胸部下行大動脈瘤　　術後から覚醒せず死亡

1951年，55歳男性の巨大な下行大動脈瘤に対して3日前に煙突から墜落死した男性の保存大動脈片を移植したが、蘇生出来なかった。

世界に先駆けた胸部大動脈瘤術



木本　誠二東京大学第二外科教授

1951年：木本らは左図の様な下行大動脈瘤に対して保存大動脈片で置換術施行
1952年：第52回日本外科学会の宿題報告
「血管外科」における保存動脈片移植等の基礎的、臨床的な研究の報告はわが国の血管外科を推進する発火点となった。

（田邊達三作成、一部改変）

合成繊維性人工血管の開発と作製

(1950年初期、DeBakey ESが母親のミシンを用いてダクロン製人工血管を作製)

(Alice LH.et al, Semin Thoracic Surg 2019)

合成繊維性人工血管の開発と臨床応用

Clinical application of a new flexible knitted Dacron arterial substitute

DeBakey ME, Cooley DA, Crawford ES, Morris Jr GC

The direct surgical treatment of various forms of aortic and arterial disease often requires a vascular replacement. Homografts were first employed successfully for this purpose and both technically and functionally have provided highly gratifying results. Their major disadvantage, however, lies in the inconvenience associated with their procurement and preparation and the fact that they are not available in sufficient quantities to meet the increasing demands for their use. For these reasons attention has been directed toward development of a satisfactory arterial substitute for homografts which would be free of these disadvantages. Various materials such as Ivalon, nylon, Orlon, Dacron, and Teflon have been used for this purpose and fashioned into tubes by different methods including heat-sealing, sewing, braiding, knitting, and weaving. In a previous publication we reviewed our experience with these various types of synthetic arterial substitutes based upon observations derived from an analysis of 317 cases in which they were employed.[1] The functional results in this series of cases were generally satisfactory and provided additional evidence that tubular fabrics of these synthetic materials could be used as substitutes for homografts. There were, however, certain disadvantages associated with most of them, particularly in their technical application. For these reasons and with the hope of overcoming some of these objections, efforts were continued toward the development of a more satisfactory arterial substitute.

As a result of these efforts and in cooperation with Professor Thomas Edman of the Philadelphia Textile Institute, a new knitting machine was designed with particular specifications to produce seamless knitted Dacron tubes in different sizes and in the form of bifurcations as well as multi-branch tubes.[2] Various types of synthetic filament yarns were tested from nylon to Teflon, but the most suitable was found to be Dacron texturized on the Flufon process. To achieve greater flexibility a process of cross-crimping the tubular knitted fabric by heat-setting was used. Various means of coating and chemically treating the fabric were tried but were discarded after

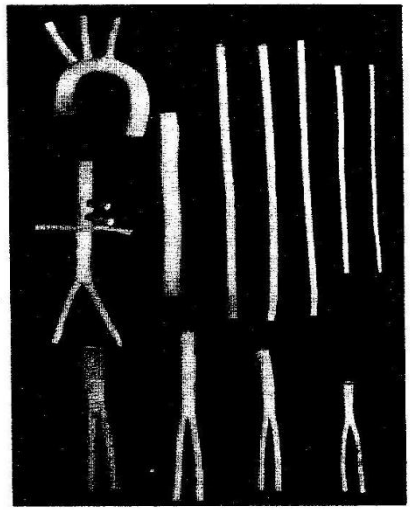


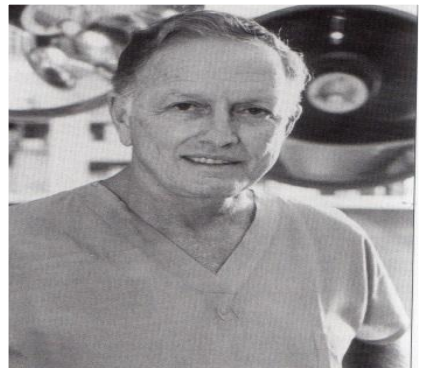
FIG. 1. Photograph showing various types and sizes of Dacron grafts for replacement of different anatomic segments of the aorta and peripheral arteries.

* Supported in part by the United States Public Health Service under Grant H-3137, the American Heart Association, the Houston Heart Association, and Mr. Arthur Hanisch.

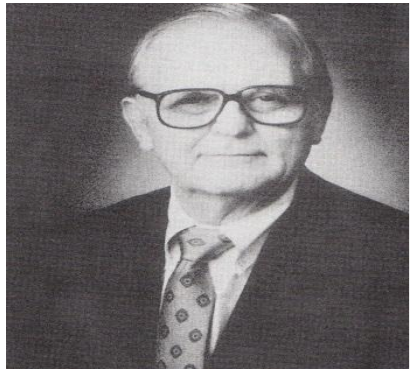
† From the Cora and Webb Mading Department of Surgery, Baylor University College of Medicine, Houston, Texas.

Ann Surg 24:862-69, 1958

DeBakey ME



Cooley DA



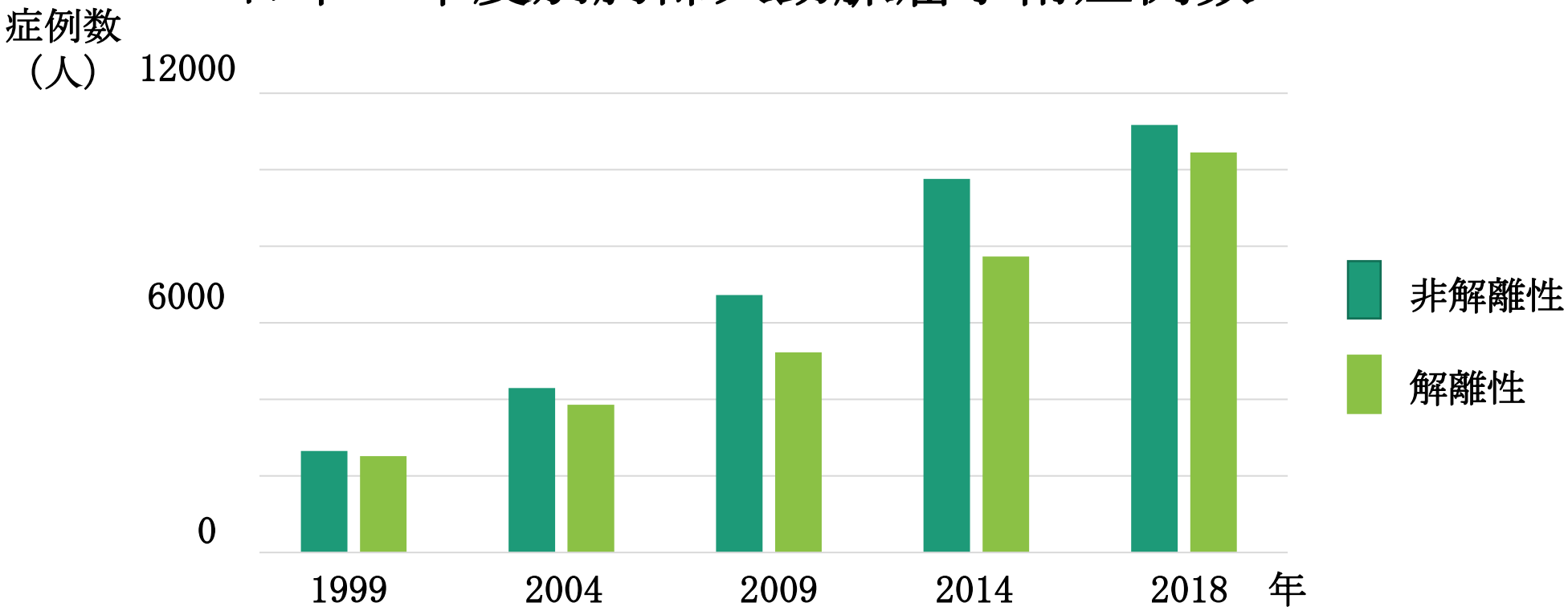
Crawford ES

Morris Jr GC

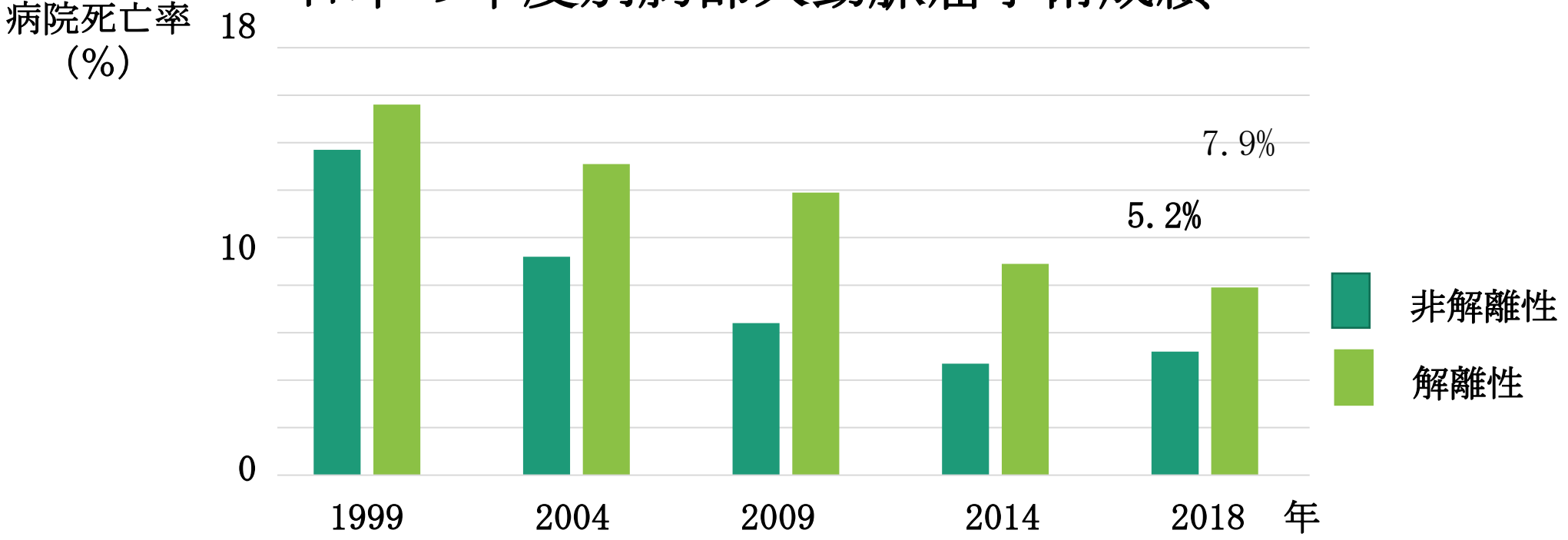
Houstonの血管外科の四天王

（田邊達三作成、一部改変）

日本の年度別胸部大動脈瘤手術症例数

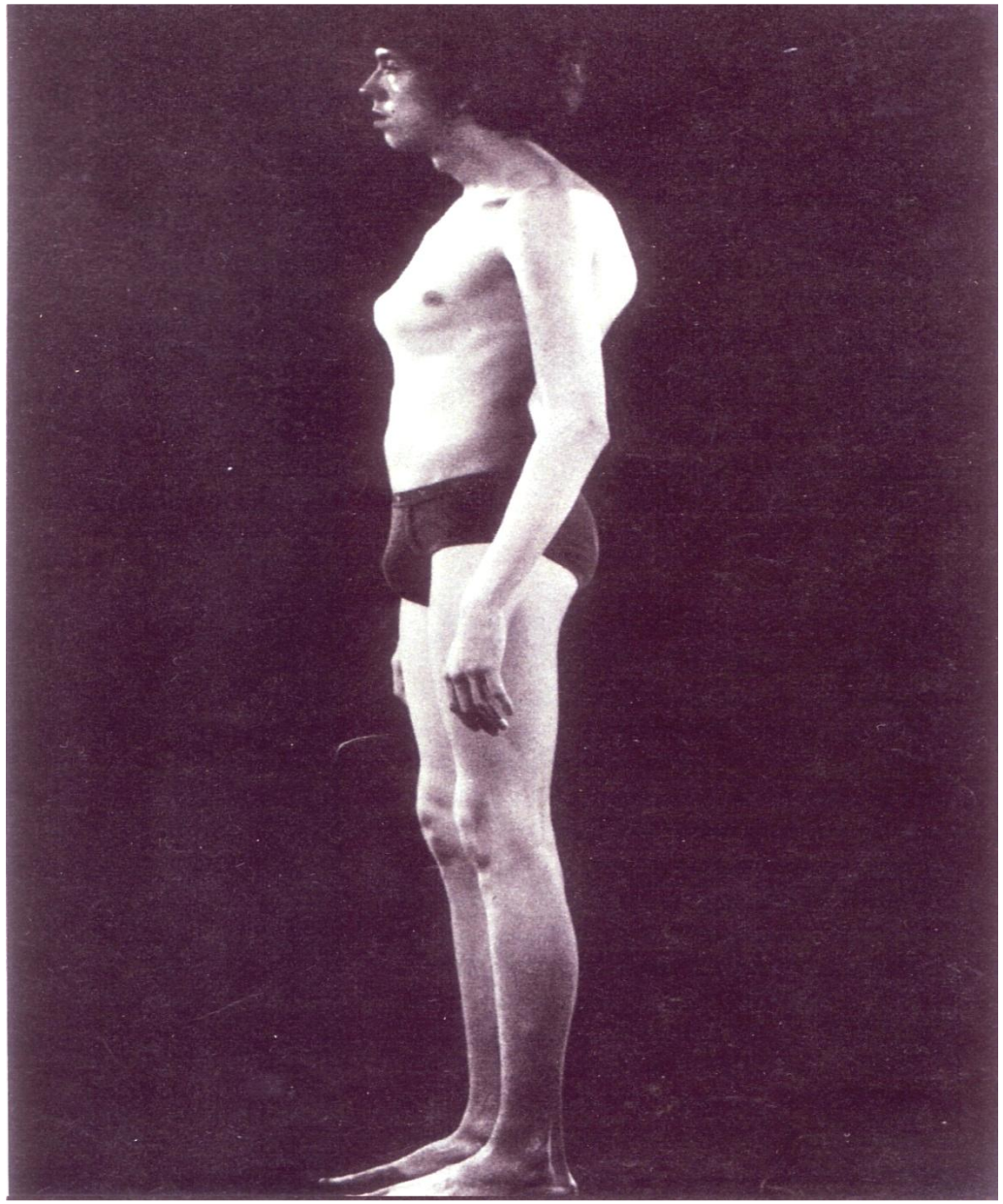


日本の年度別胸部大動脈瘤手術成績



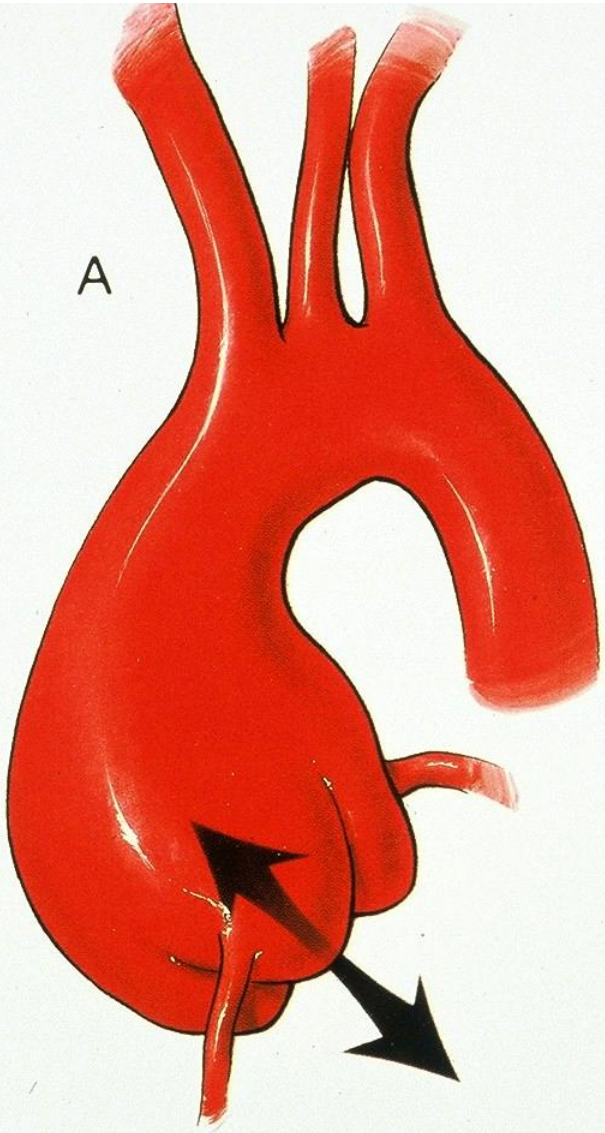
大動脈基部置換術

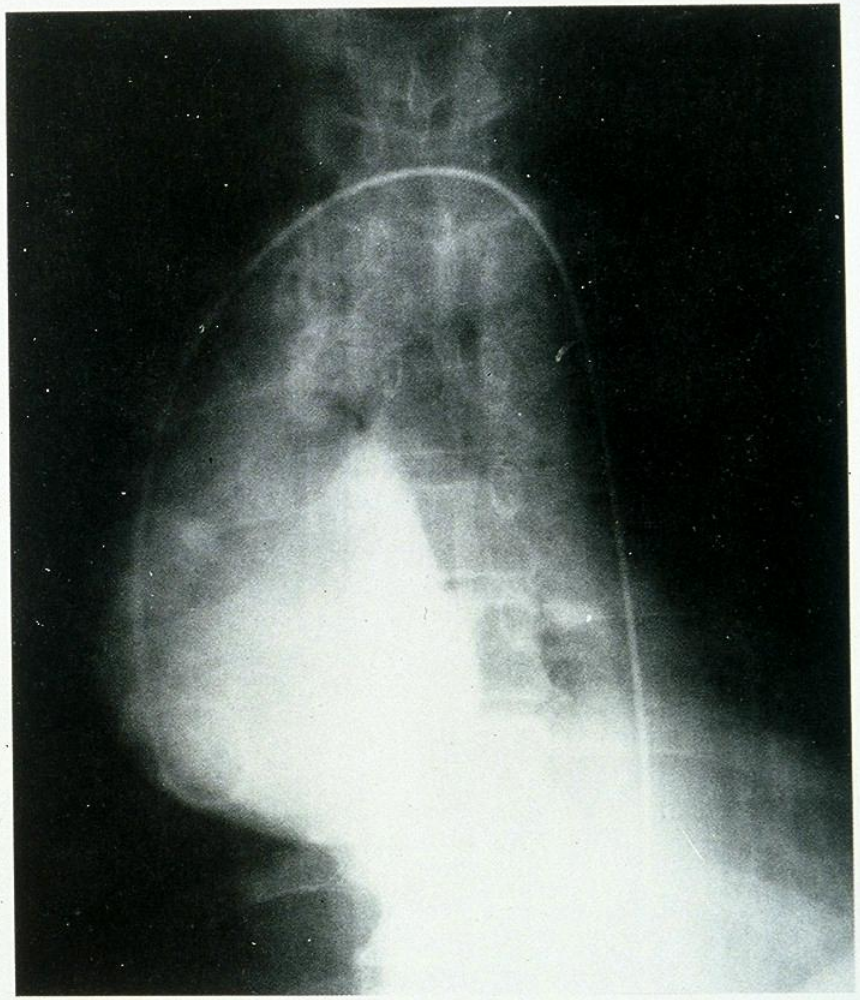
いちまいの絵（マルファン症候群）



遺伝性疾患
長い四肢
骨格異常
クモ指症

バルサルバ洞
の拡大



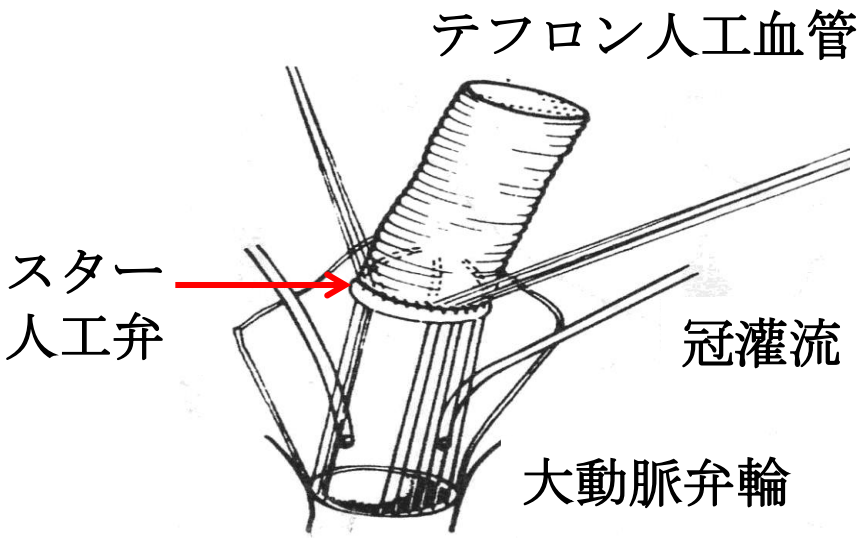


大動脈弁閉鎖不全症

大動脈弁輪拡張症

画期的アイデアのベントール手術

Hugh Bentall (1920-2012)
ハンマースミス病院教授



Thorax 23:38, 1968

A technique for complete replacement of the ascending aorta

HUGH BENTALL AND ANTONY DE BONO

From the Royal Postgraduate Medical School, London, and Hammersmith Hospital

A technique for complete replacement of the aortic valve and ascending aorta in cases of aneurysm of the ascending aorta with aortic valve ectasia is described. The proximal aortic root was too attenuated to afford anchorage to the aortic prosthesis, so this was sutured to the ring of a Starr valve and the prostheses were inserted *en bloc*. The ostia of the coronary arteries were anastomosed to the side of the aortic prosthesis.

Aneurysmal dilatation of the ascending aorta is often associated with ectasia of the aortic valve ring and presents clinically as aortic incompetence. In Marfan's syndrome or cystic medial necrosis this may develop with dramatic suddenness in an ostensibly healthy individual.

The dilatation of the valve ring makes repair or replacement with other than a prosthetic valve difficult. The aneurysm, which is either a true dilatation or dissection, is best treated by excision and replacement with a tubular prosthesis, as the wall is invariably attenuated. This is not difficult provided that the aorta distal to the aneurysm and proximal to the arch is suitable for anastomosis.

Proximally, in most cases, the aortic prosthesis can be sutured to a rim of aorta, leaving the coronary ostia undisturbed, while a valve prosthesis is placed in the usual sub-coronary position (Cooley, Bloodwell, Beall, Hallman, and De Bakey, 1966).

However, it sometimes happens that the root of the aorta is so involved in the disease process that the wall is too attenuated to be sutured to the proximal end of the aortic prosthesis. In this situation the management of the coronaries is the main concern of the surgeon.

CASE REPORT

A man aged 33 years had been in excellent health until a few months before admission, when his wife had noticed a loud cardiac murmur and he developed signs and symptoms of gross aortic regurgitation. Angiocardiography showed a large aneurysmal dilatation of the ascending aorta, not involving the vessels of the arch but associated with free aortic regurgitation. He was in incipient cardiac failure with an effective cardiac output of 1.8 l./min./m.^{2}

OPERATION A mid-sternal thoracotomy revealed a large globular dilatation of the ascending aorta. Its bulging inelastic wall was so thin that blood could be seen eddying within. Figure 1 gives an idea of the attenuation of the wall.

Total cardiopulmonary bypass was established, and, after cross-clamping the aorta distal to the aneurysm, the aorta was opened, and the coronaries were cannulated and perfused in the usual way. The aortic valve ring was much dilated and the wall was extremely thinned down to the ring.

It was clear that it would not be possible to join the aortic wall above the coronaries to an aortic prosthesis. It was therefore decided to suture the tube prosthesis directly to the ring of a Starr valve. A No. 13 Starr valve was sutured to one end of a crimped Teflon aortic prosthesis, as shown in Figure 2. The aortic cusps having been excised, sutures were placed in the aortic ring and through the Starr valve ring. These were tied, fixing the Starr valve and the attached Teflon tube.

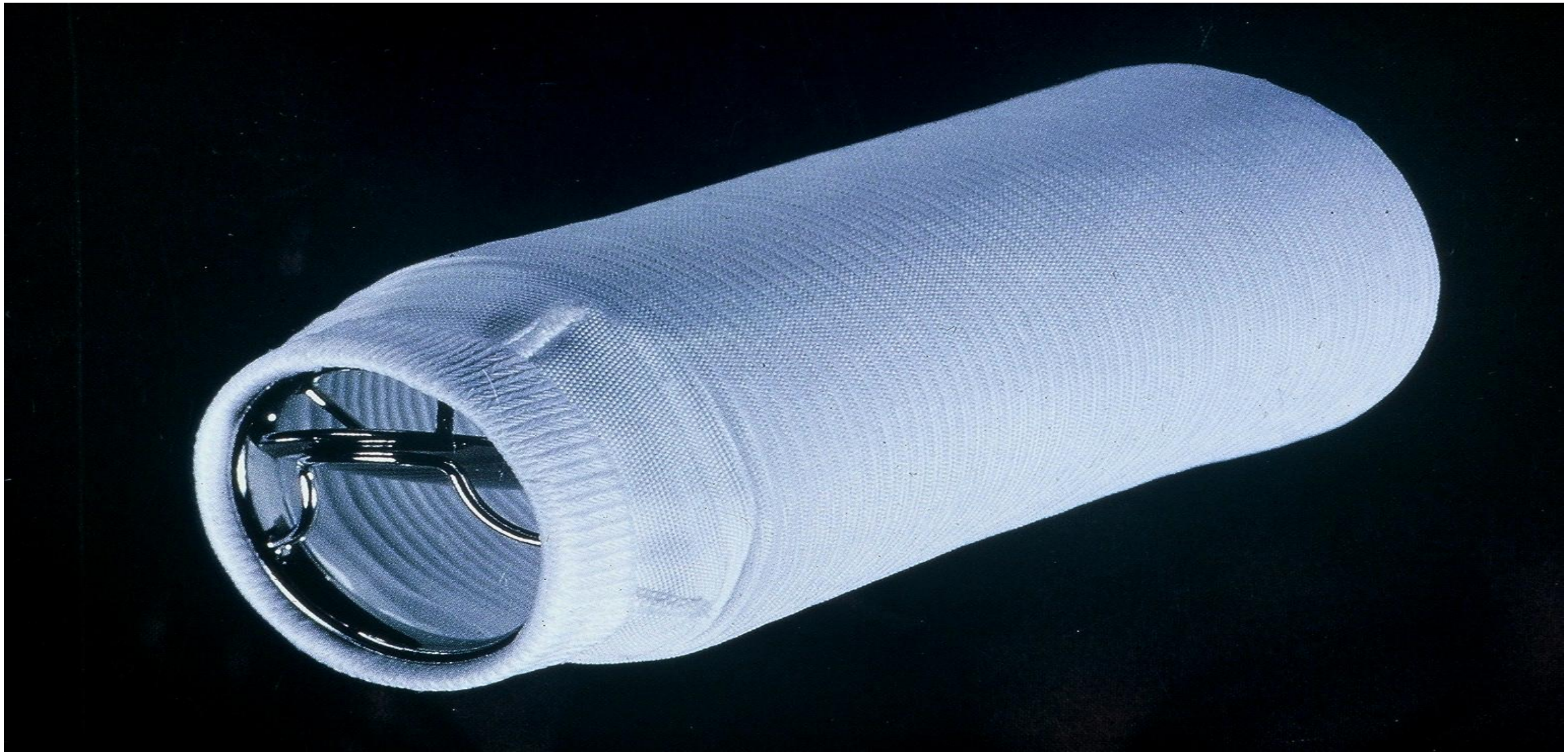
At this stage the coronary cannulae were outside the lumen of the aortic replacement. Holes were cut in the aortic prosthesis at the site of the coronary ostia, which were then re-cannulated, this time through the lumen of the tube (Fig. 3). The aortic wall was sutured to the perimeter of the holes in the Teflon tube, thus reincorporating the coronary ostia within the new aorta.

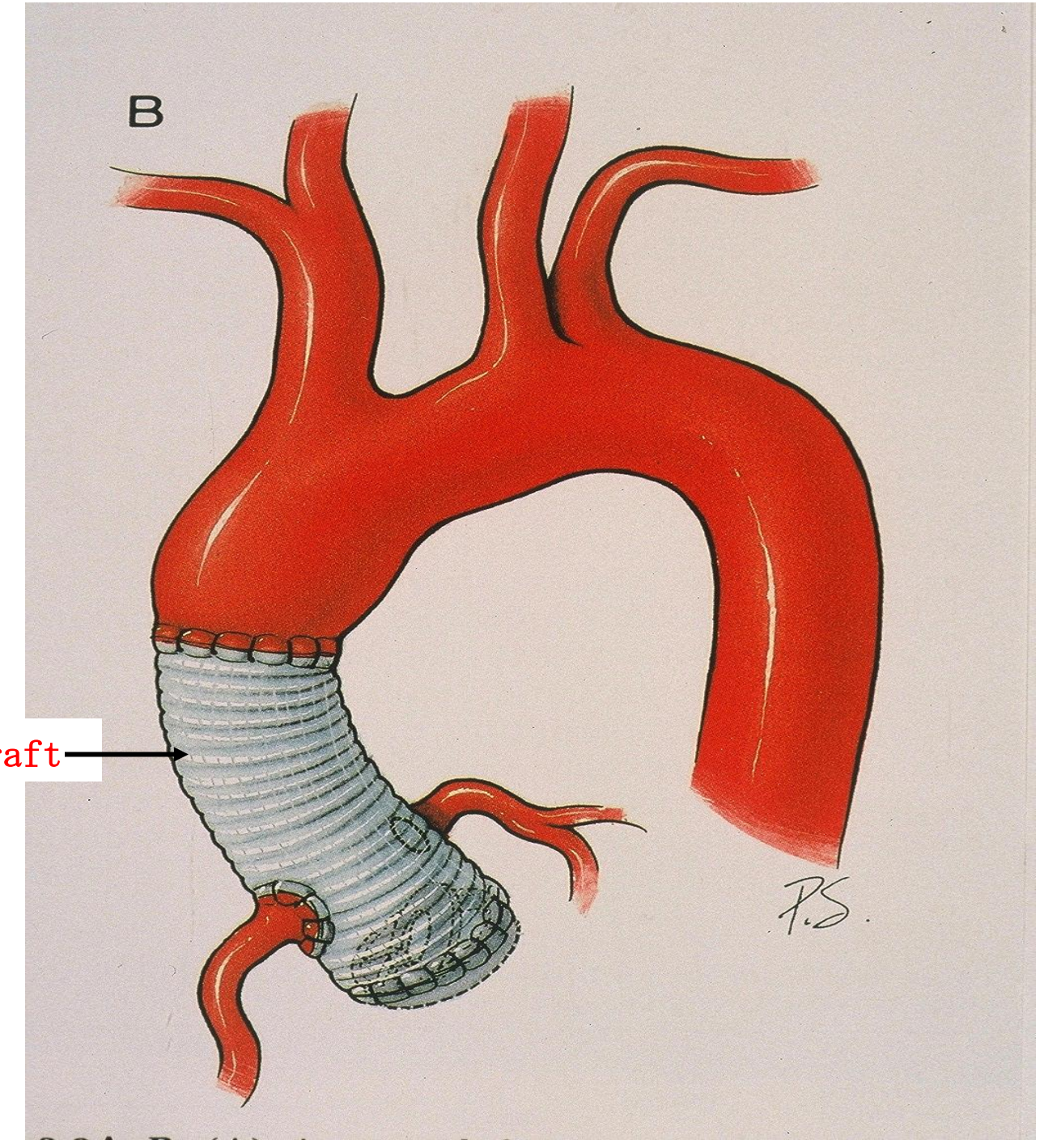
The distal anastomosis was then completed, leaving a vertical slit (Fig. 3 (5)) through which the coronary cannulae were removed and air was evacuated. This was then closed with a clamp while the aortic clamp was released and retrograde coronary perfusion was started again without any delay. The wall of the aneurysm was closed over the prosthesis.

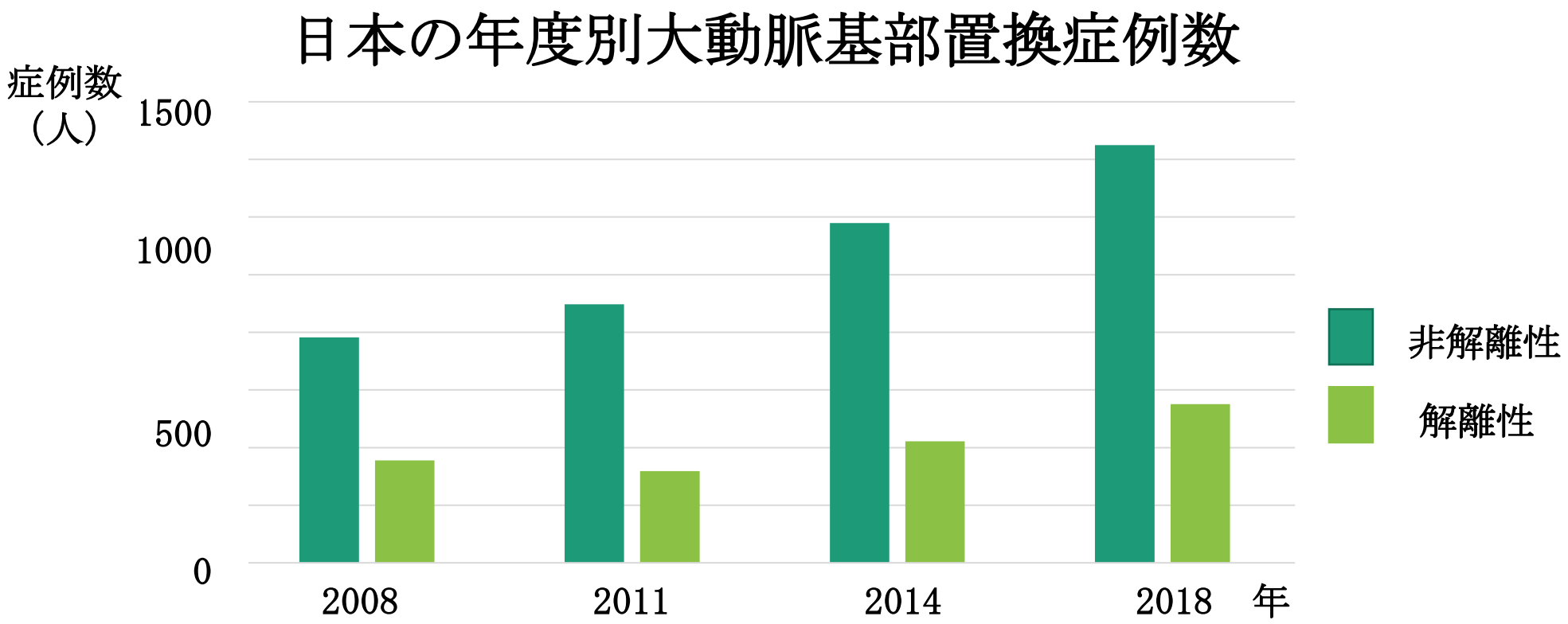
The patient made an uneventful recovery and remains well after nine months.

(田邊達三作成、一部改変)

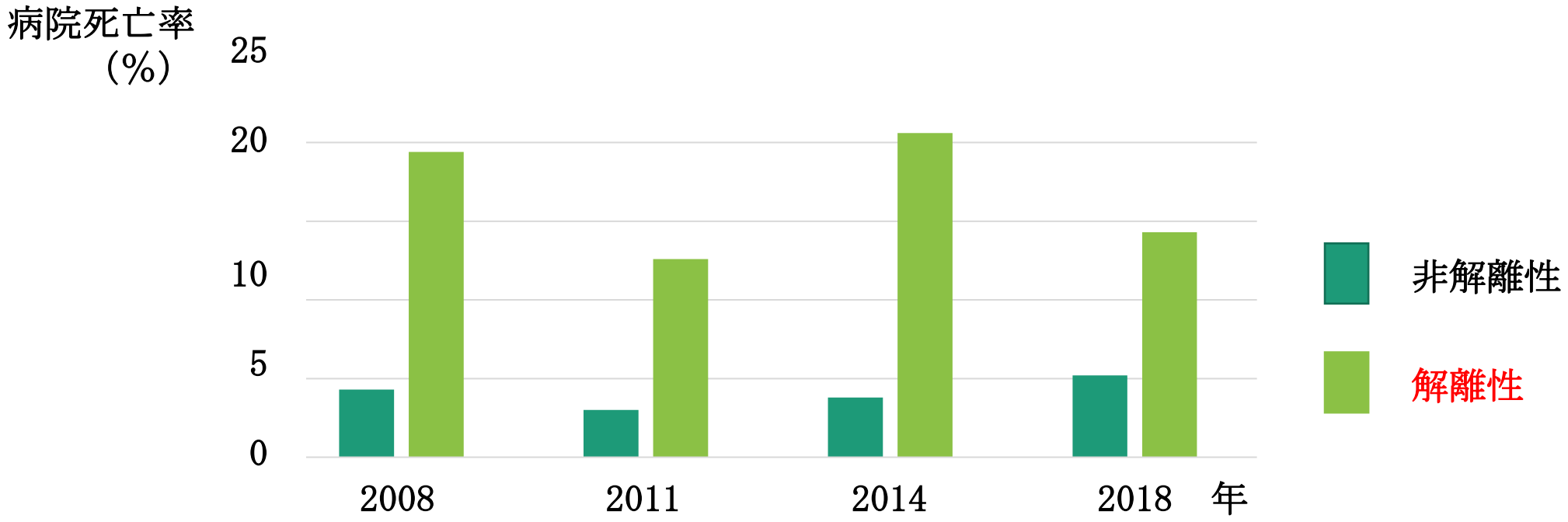
人工弁付き人工血管（composite graft）




B
Composite graft

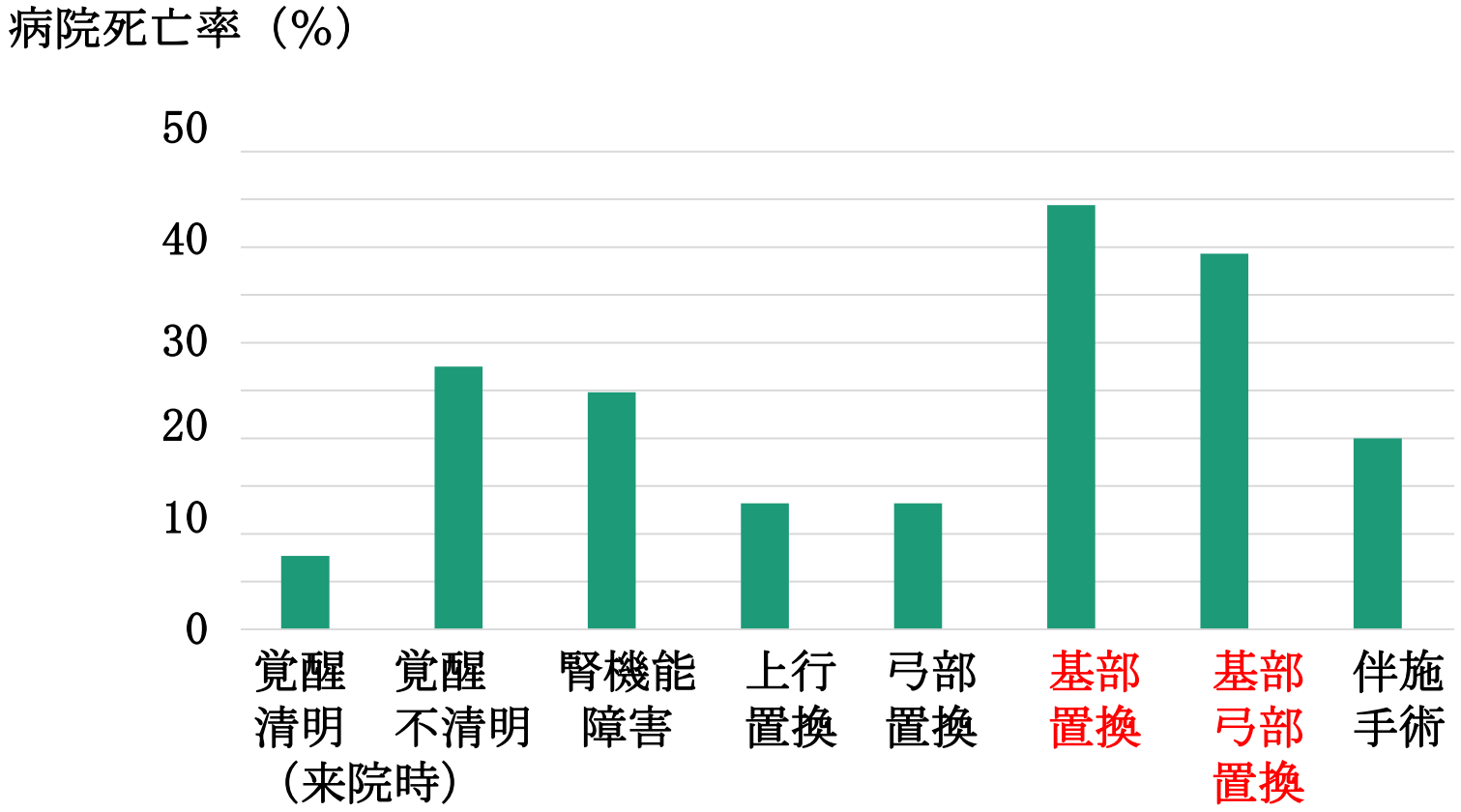

日本の年度別大動脈基部置換症例数
症例数
（人）
1500
1000
500
0
2008
2011
2014
2018
年
非解離性
解離性

日本の年度別大動脈基部置換術成績

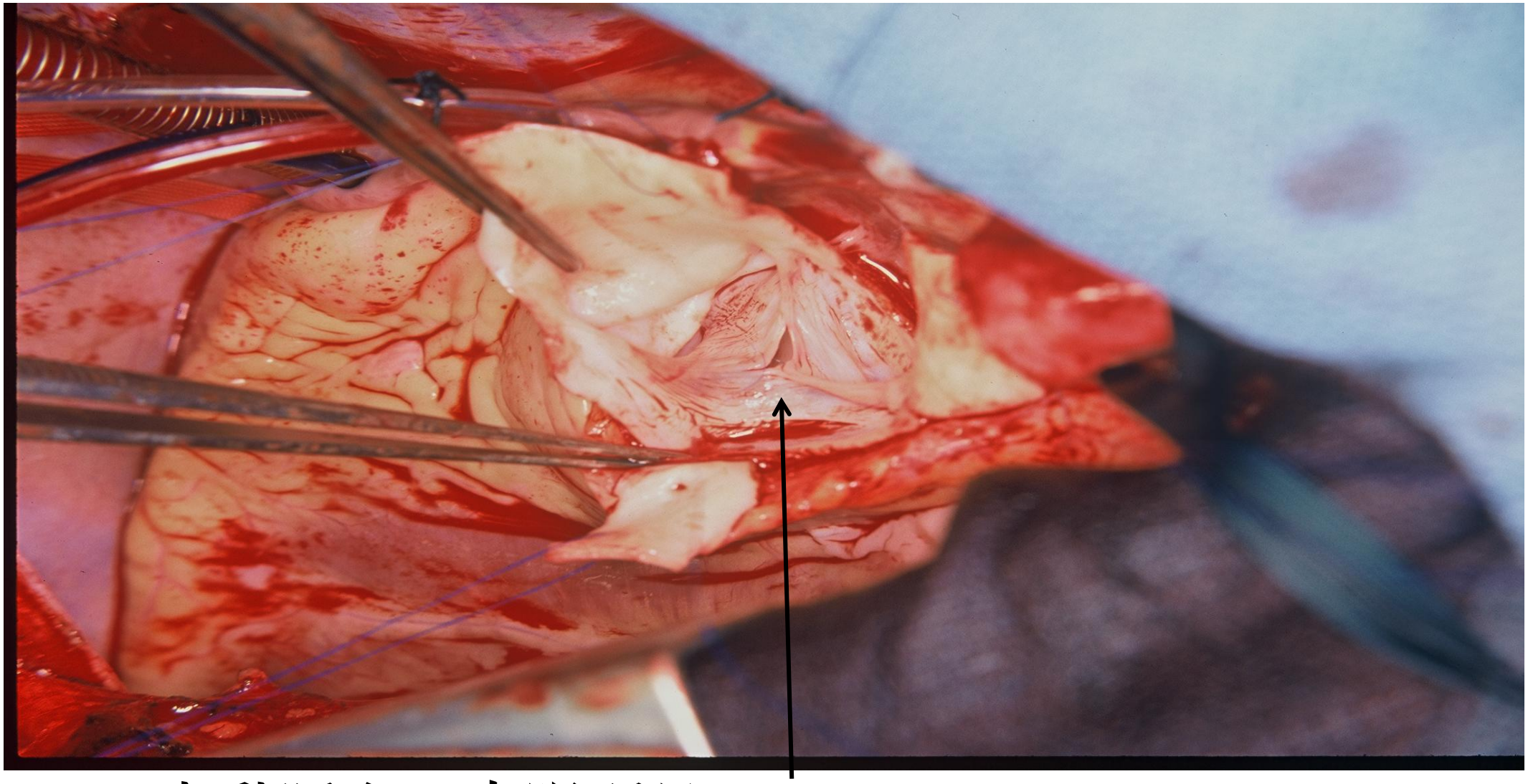


急性大動脈解離例の死亡率（18%）が高値であった

80歳以上の急性A型大動脈解離手術症例における死亡リスク増加因子と病院死亡率



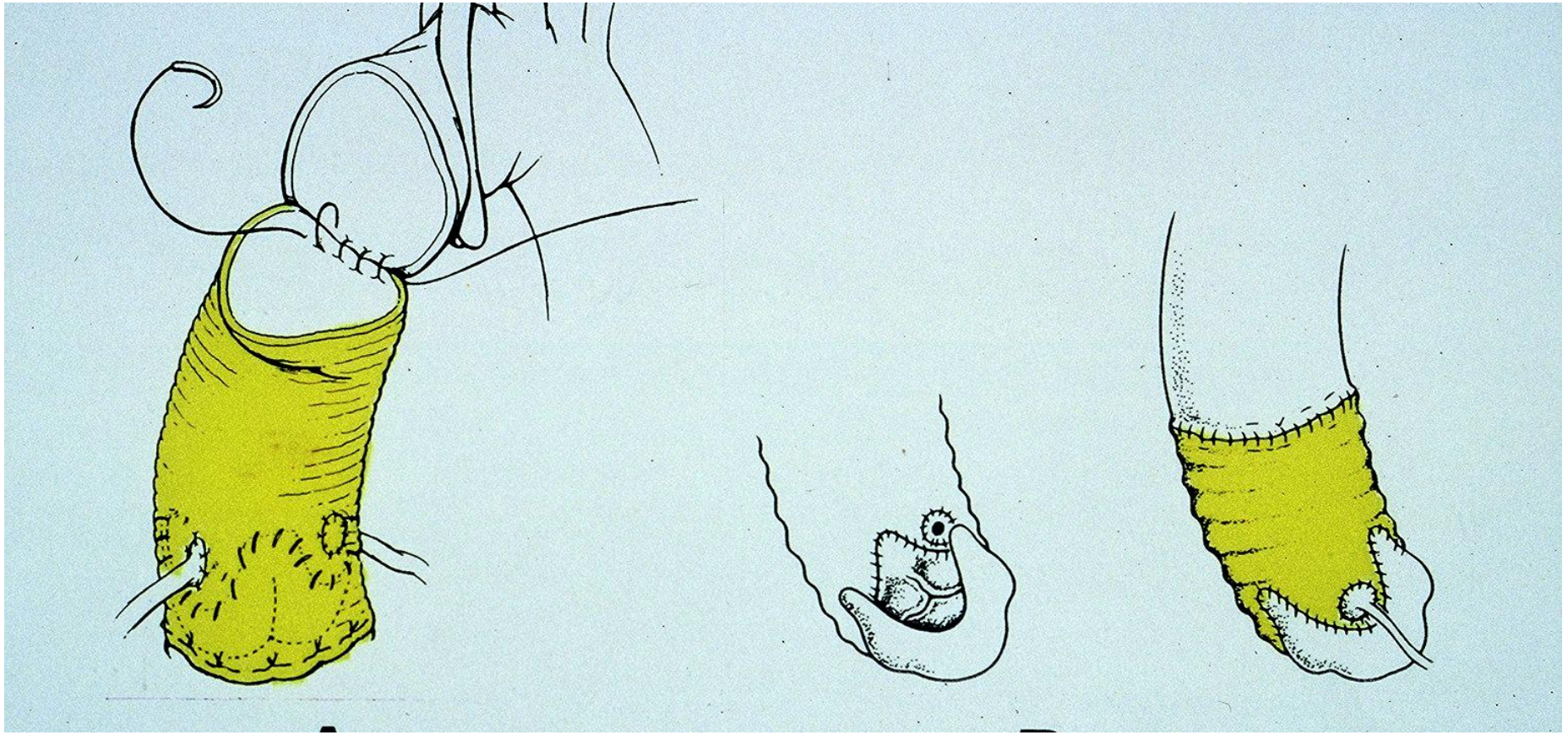
（佐々木康之輔, 他. 第50回日本心臓血管外科学会学術総会）



大動脈弁の肉眼所見（大動脈弁は正常に保たれている）

（ 18歳，マルファン症候群，大動脈弁輪拡張症 ）

自己大動脈弁温存基部置換術



Reimplantation法

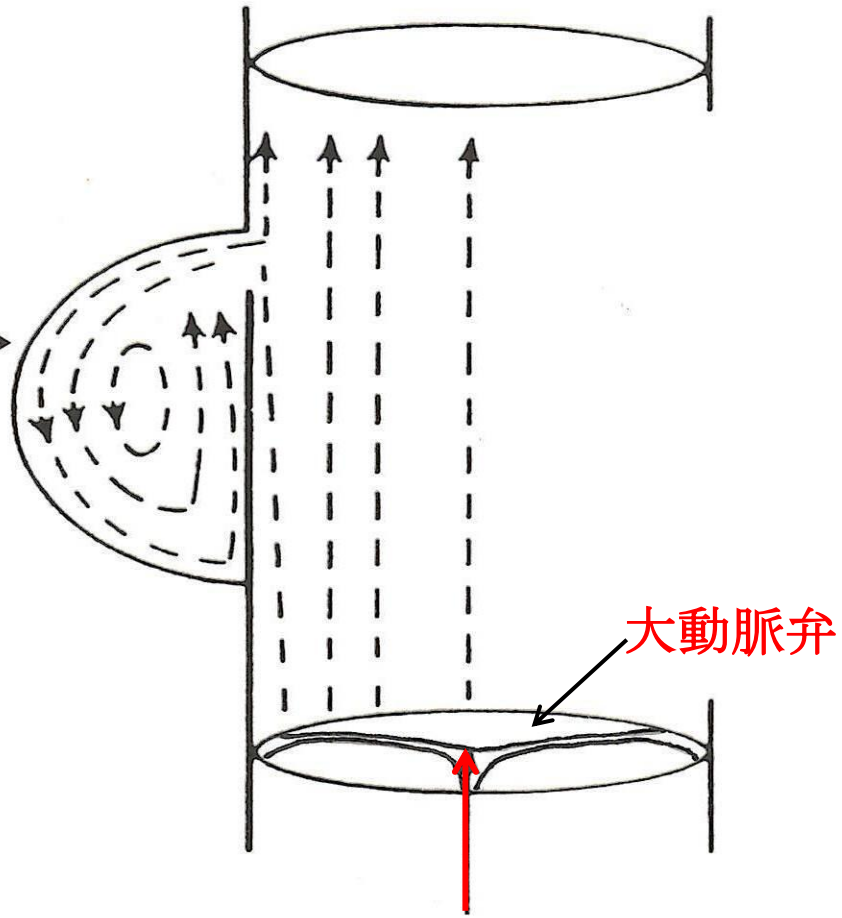
(大動脈弁輪部を人工血管で固定)

Remodeling法

(大動脈弁輪部を生理的に保つ)

バルサルバ洞

(洞内の渦流が
大動脈弁の
開閉、また
ストレスに関与)



大動脈基部の血流動態と弁の開閉

(Bellhouse. et al, 1972, 一部改変)

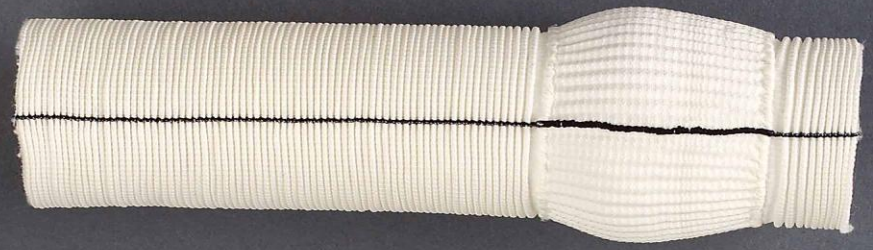
美と科学の融合

大動脈基部の血流動態

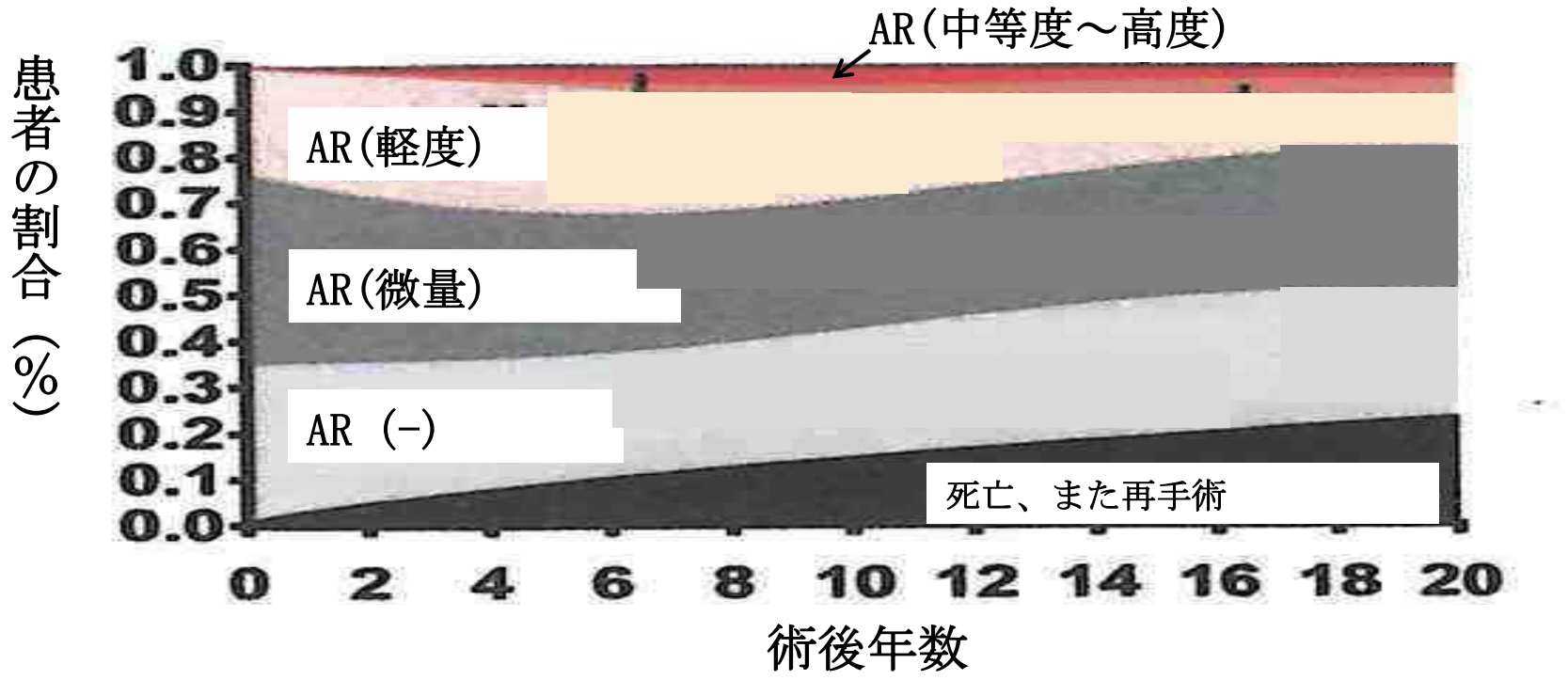
Leonardo da Vinci(レオナルド ダ ビィンチ,1513)

大動脈基部形態類似のグラフト開発(2000年)

：Valsalva Graft（大動脈弁へのストレス軽減の可能性）



Reimplantation法による
大動脈弁温存基部置換術後長期成績
−大動脈弁閉鎖不全(AR)の程度−



(David TE. J Thorac Cardiovasc Surg 2017)

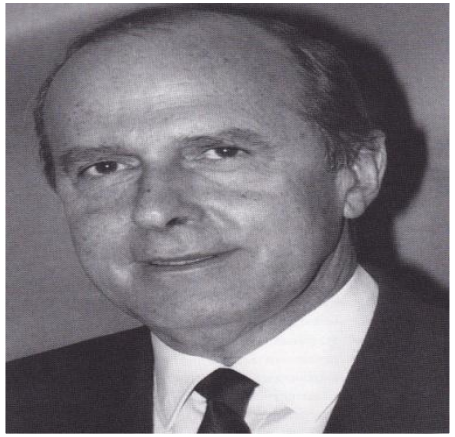
上行・弓部大動脈置換術

画期的アイデアの
エレファントトランク法

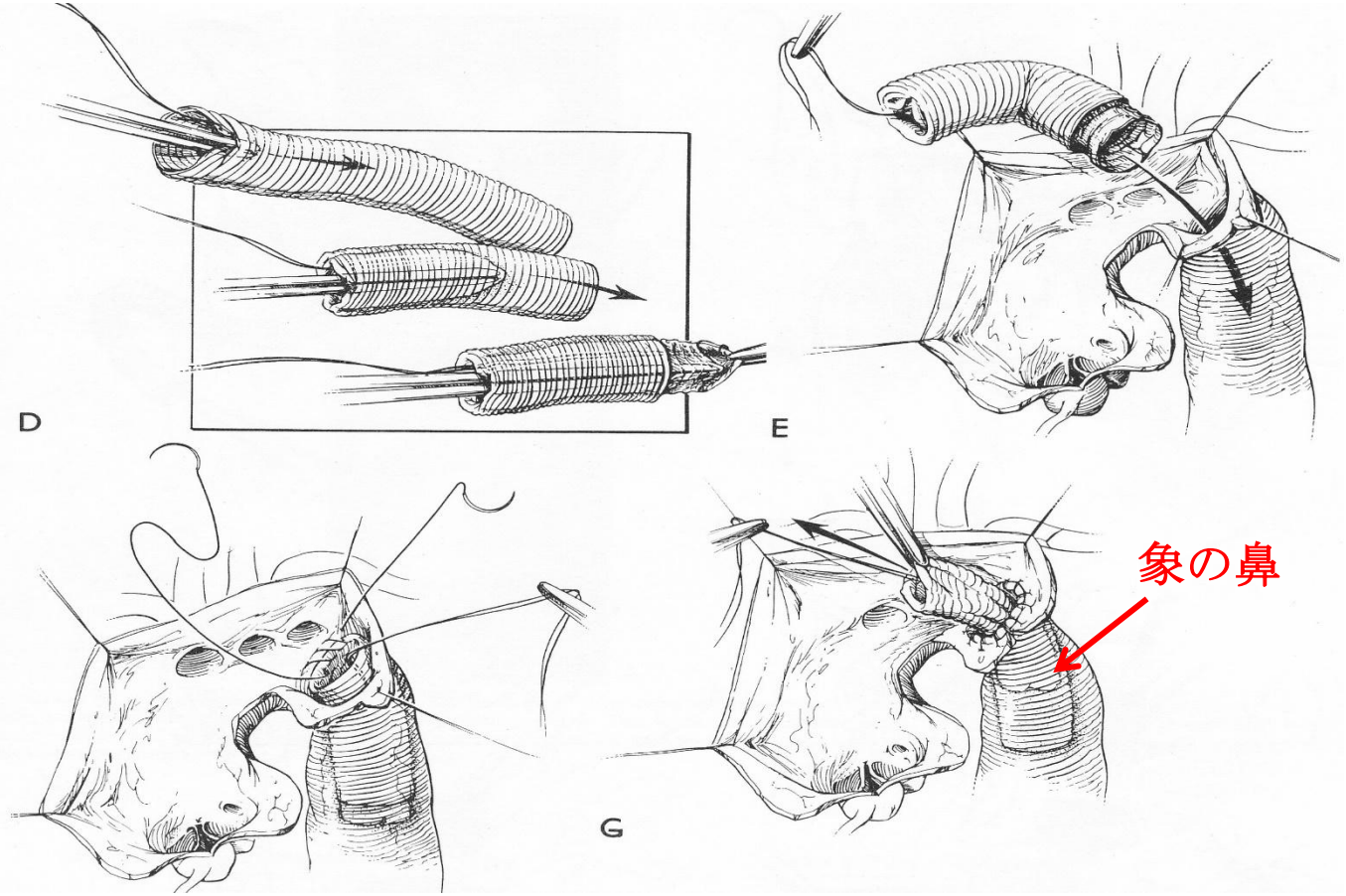
Hans Borst

(1972～

ハノーバー大学教授



本法は広範囲大動脈瘤の
2期的手術を容易にする目的
で考案されたが、後に弓部
大動脈瘤の末梢側吻合部の
補強目的に応用された。



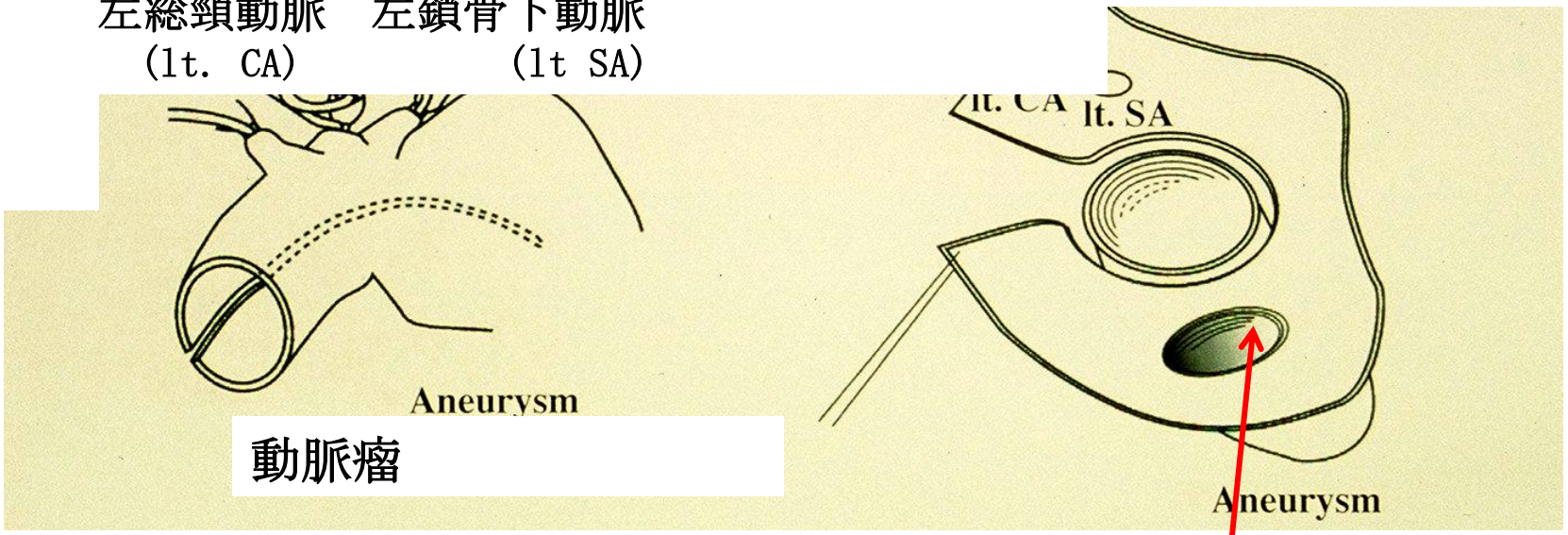
Borst HG et al. Extensive aortic replacement using "elephant trunk" prosthesis Thorac Cardiovasc Surg 31:37, 1983

（田邊達三作成、一部改変）

弓部大動脈置換術

左総頸動脈　左鎖骨下動脈
(lt. CA)　(lt SA)

腕頭動脈
(BA)



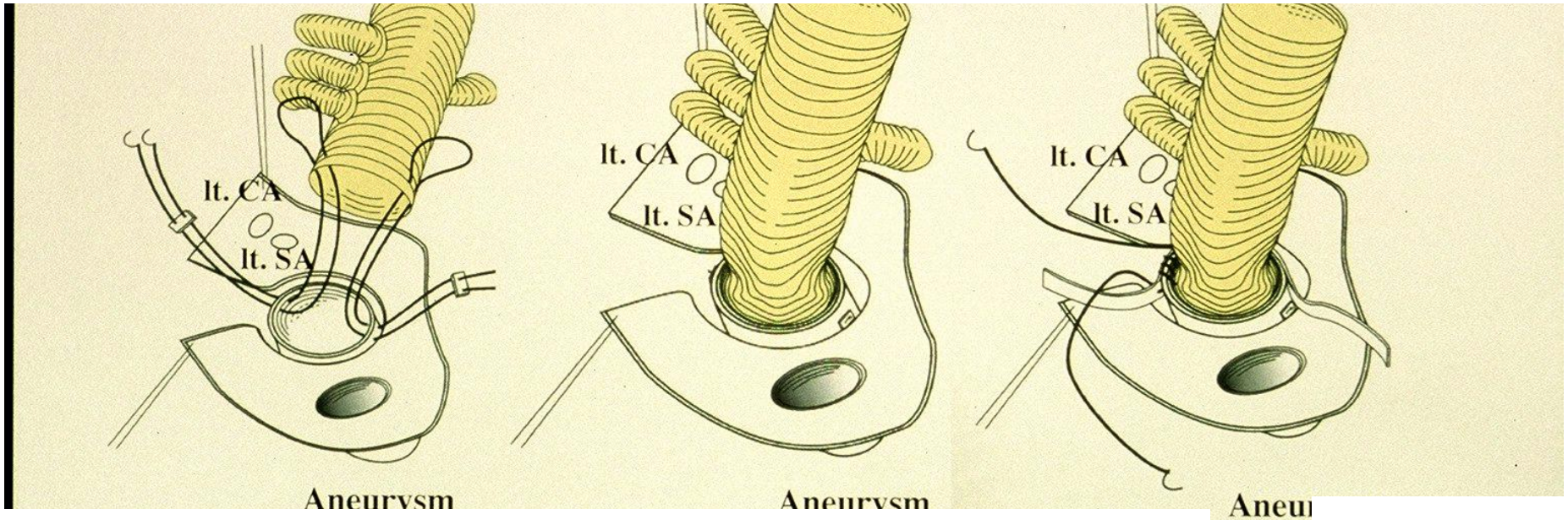
動脈瘤

動脈瘤

大動脈切開

下行大動脈の横切

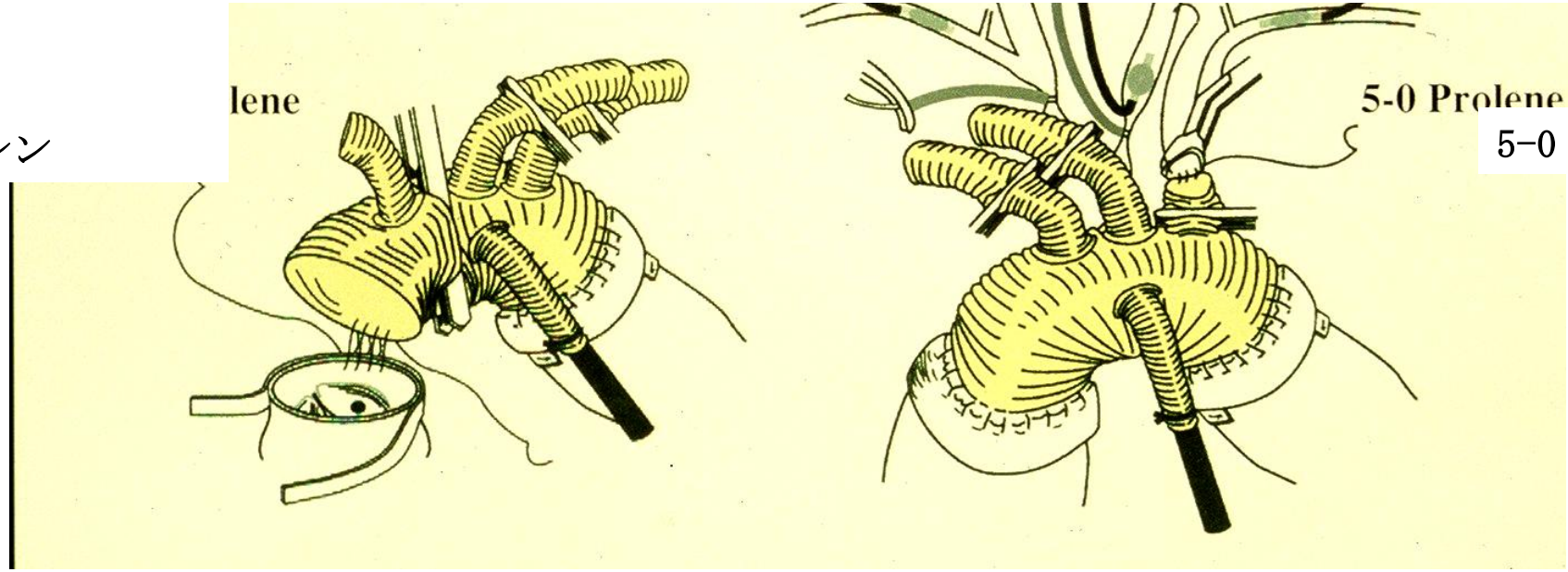
弓部大動脈置換術
末梢側吻合法



大動脈瘤

弓部大動脈置換術
中枢側吻合、および弓部分枝再建法

4-0 プローレン



5-0 プローレン

弓部大動脈置換術時の脳保護法

1. 順行性脳灌流法（選択的脳分離灌流法）

2. 逆行性脳灌流法：低体温を基本とした保護法で、深度低体温循環停止法と保護効果はほぼ同等

3. 深度低体温循環停止法

弓部大動脈置換術時の脳保護法に関するメタ分析

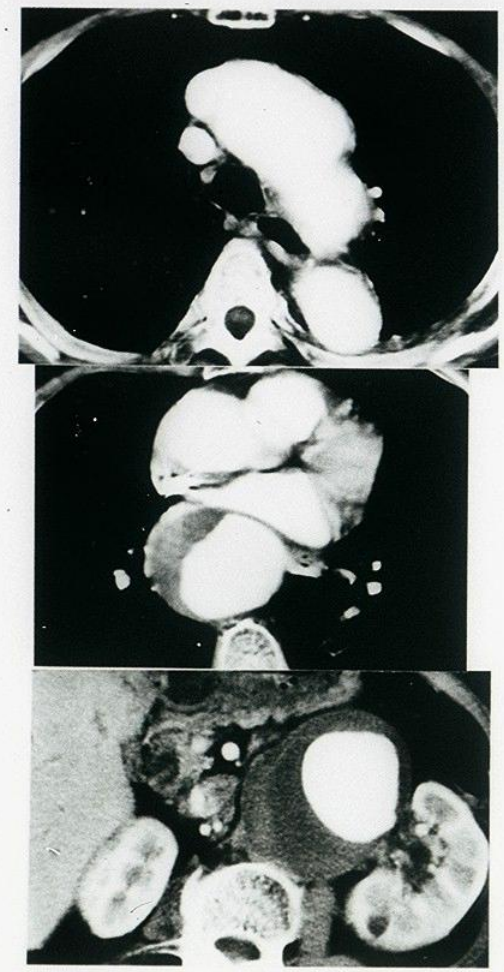
	平均脳保護時間（分）	一時的脳障害発生率（%）	永続的脳障害発生率（%）	死亡率（%）
深度低体温循環停止群	28.6	13.9	8.0	14.2*
順行性脳分離灌流法群	46.8	11.1	6.8	8.5*

* p=0.008

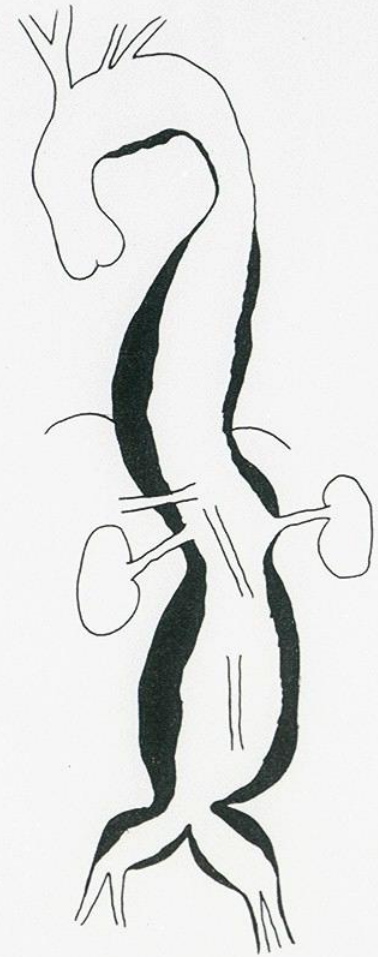
(Tian DH et al. Ann Cardiothorac Surg 2013)

順行性脳分離灌流法群の死亡率が有意に低下であり、その理由として脳障害発生率の低下が関与した。

胸腹部大動脈瘤（Crawford III, 68才, 男性）

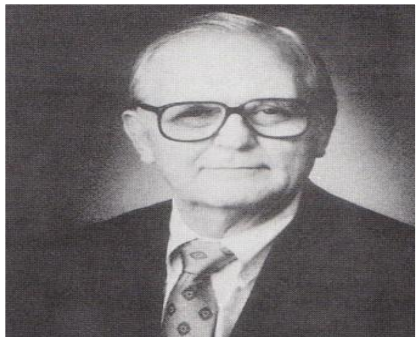


術前ＣＴ



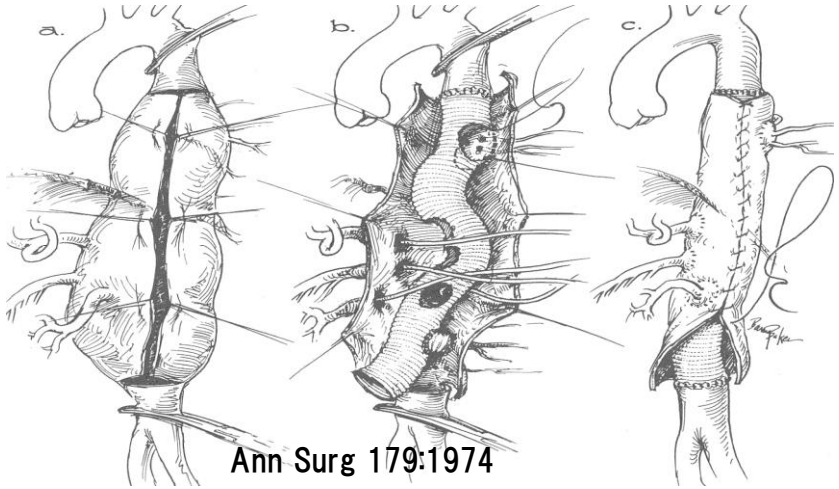
胸腹部大動脈置換手術成績改善の最大の貢献者

Stanley Crawford (1992-1992)



１９５６年からベイラー大学で
ドゥベキー，クーリーと共同研究

Crawford S. Thoraco-abdominal and abdominal aortic aneurysms involving renal, superior mesenteric , celiac arteries.
Ann Surg 179:763-72, 1974



Ann Surg 179:1974

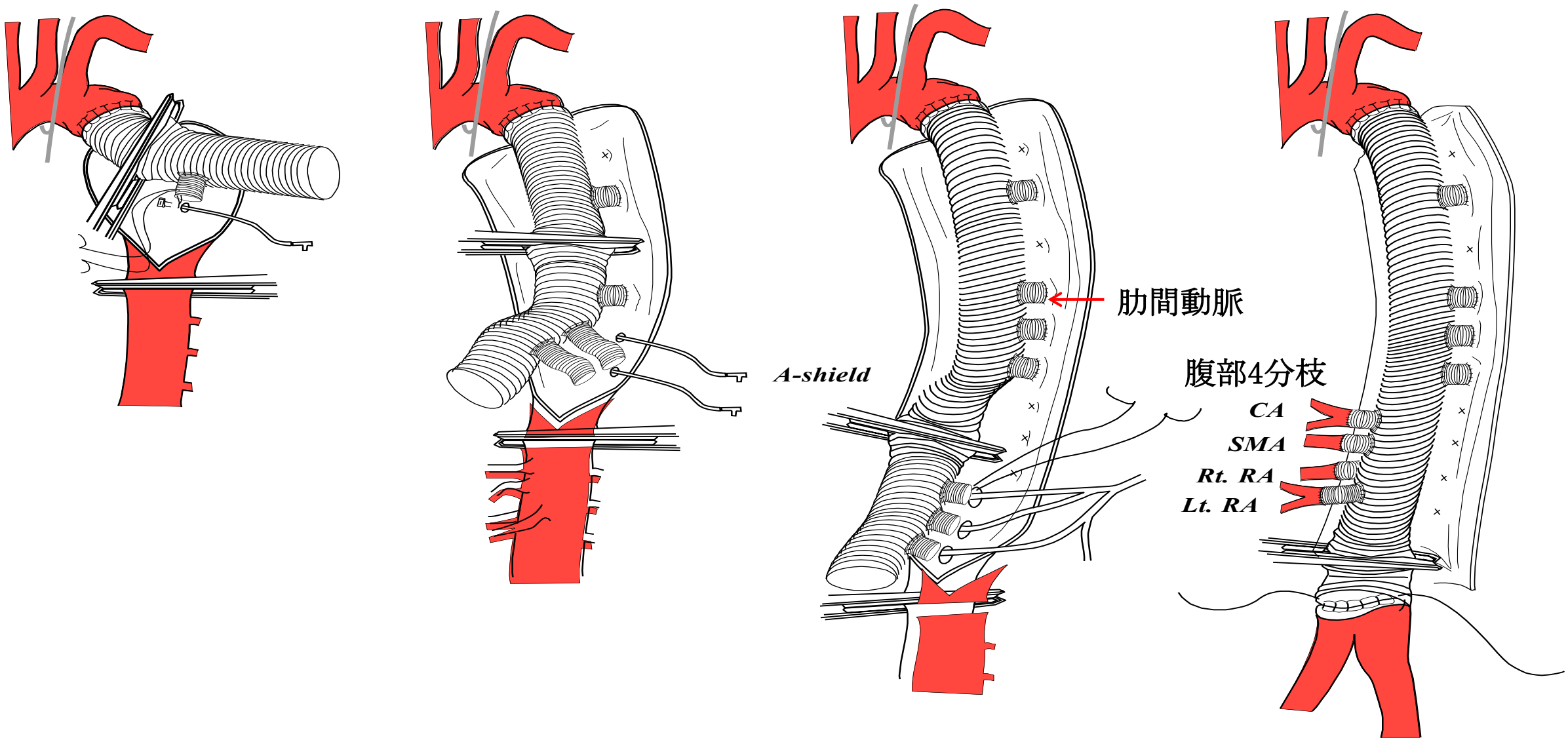
人工心肺、シャント非使用下のInclusion法、
補助手段を用いないので、優れた技術を必要とした。

（田邊達三作成、一部改変）

Aneurysm Man
(Crawford ES のイラスト)

(Alice LH.et al, Semin Thoracic Surg 2019)

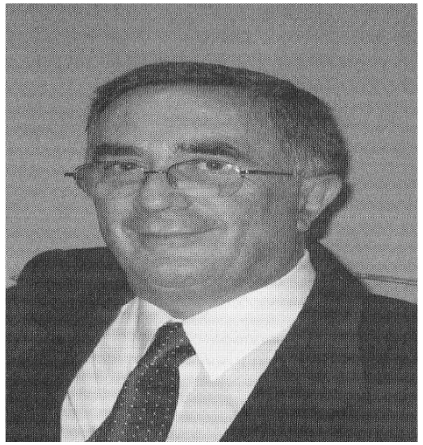
胸腹部大動脈置換術



血管内ステントグラフトによる
大動脈瘤の治療

腹部大動脈瘤に対する拡張型ステント最初の臨床応用（1990年）

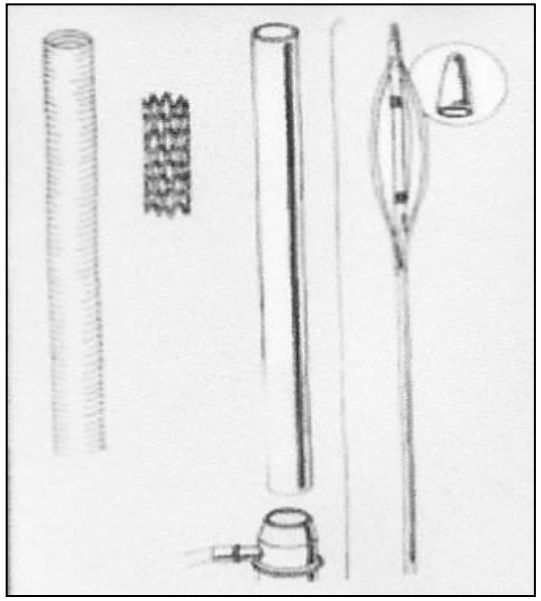
Juan Parodi　（1942～）

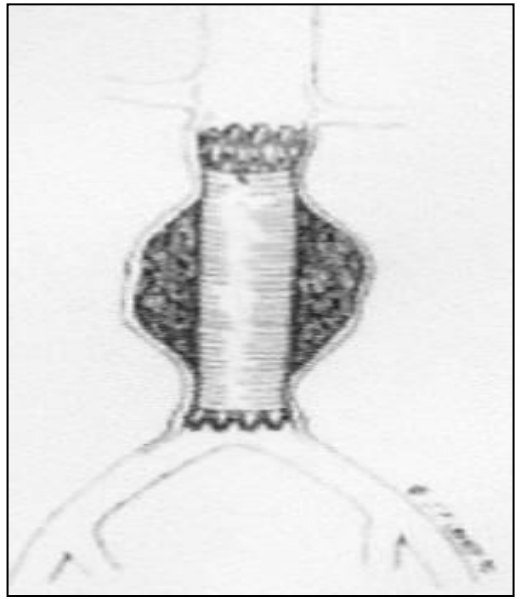


ワインステート大学教授

大動脈瘤手術の画期的な報告

Parodi J et al. Transfemoral intraluminal graft implantation for abdominal aortic aneurysms. Ann Vasc Surg 5:491,1991



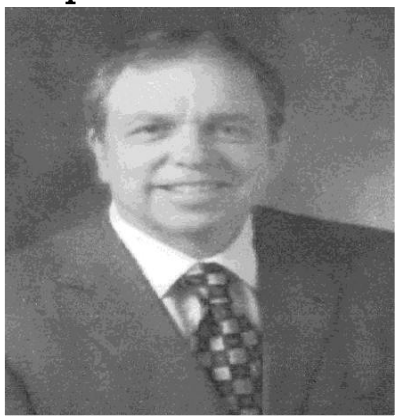


苦闘のあゆみ：

- 低侵襲の手術法として、針金を軸に人工血管を巻いて移植：失敗
- 1990年, 拡張型ステント作成

胸部大動脈瘤に対するステントグラフトの最初の臨床応用

(Development of TEVAR)



Michel D Dake

スタンフォード大学教授

Dake MD et al. Transluminal placement of endovascular stent-grafts for the treatment of descending thoracic aortic aneurysms. N Engl J Med 331:1729, 1994

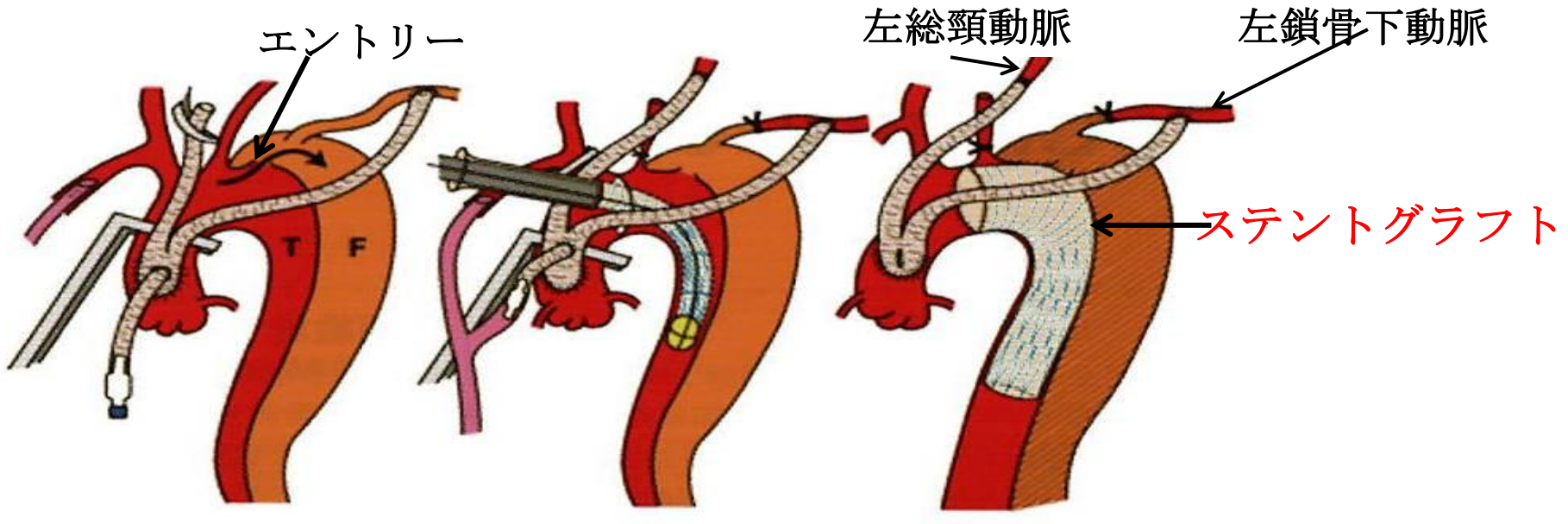
METHODS: We evaluated the feasibility, safety, and effectiveness of transluminally placed stent-graft to treat descending thoracic aortic aneurysms in 13 patients over a 24-month period. Atherosclerotic, anastomotic, and post-traumatic true or false aneurysms and aortic dissections were treated. The mean diameter of the aneurysms was 6.1 cm (range, 5 to 8). The endovascular stent-grafts were custom-designed for each patient and were constructed of self-expanding stainless-steel stents covered with woven Dacron grafts.

RESULTS: Endovascular placement of the stent-graft prosthesis was successful in all patients. There was complete thrombosis of the thoracic aortic aneurysm surrounding the stent-graft in 12 patients, and partial thrombosis in 1. Two patients initially had small, residual patent proximal tracts into the aneurysm sac, but both tracts thrombosed within two months after the procedure. In four patients, two prostheses were required to bridge the aneurysm adequately. There have been no deaths or instances of paraplegia, stroke, distal embolization, or infection during an average follow-up of 11.6 months. One patient with an extensive chronic aortic dissection required open surgical graft replacement four months later because of progressive dilatation of the arch.

CONCLUSIONS: These preliminary results demonstrate that endovascular stent-graft repair is safe in highly selected patients with descending thoracic aortic aneurysms. This new method of treatment will, however, require careful long-term evaluation.

弓部、および胸腹部大動脈領域における
新しいステントグラフト法の開発

弓部大動脈疾患に対する
オープンステントグラフト法



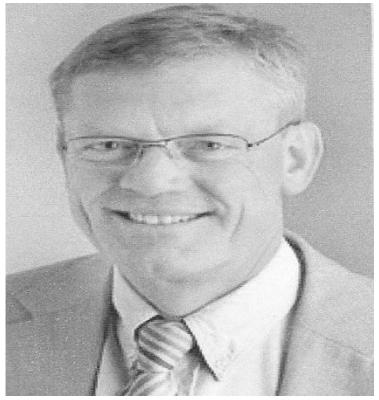
弓部動脈にエントリーのある大動脈解離症例に対する
左総頸動脈と左鎖骨下動脈へのバイパス後、
ステントグラフト挿入

(Kato M, Circulation 94(Suppl), 1996)

Frozen エレファント
トランク法

Matthias Karck

ハイデルベルグ
大学心臓血管
外科教授



Axel Haverich

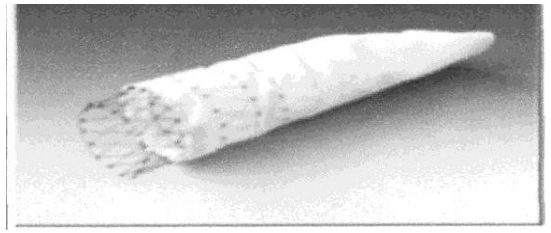
ハノーバー大学教授

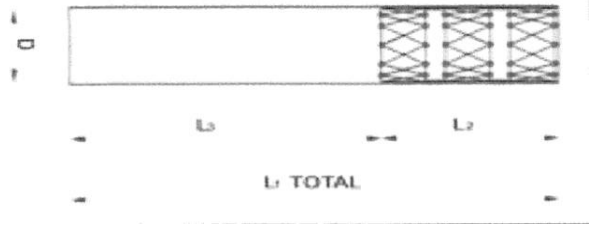
The frozen elephant trunk technique: A new treatment for thoracic aortic aneurysms

Matthias Karck, MD[a], Ajay Chavan, MD[b], Christian Hagl, MD[a], Holger Friedrich, MD[a], Michael Galanski, MD[b], Axel Haverich, MD[a] *Hannover, Germany*

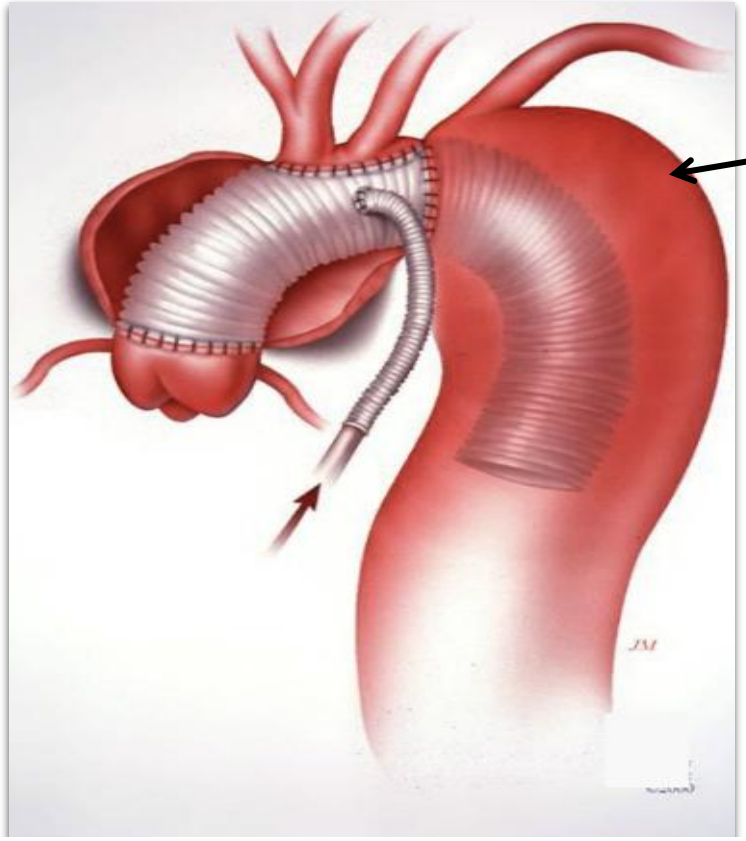
Thorac Cardiovasc Surg 125:1550-53, 2003

開放された弓部大動脈より順行性に下図ステントグラフトを胸部下行大動脈に挿入[偽腔の血栓化、大動脈瘤のリモデリングの促進により大動脈病変を固定化（frozen)]

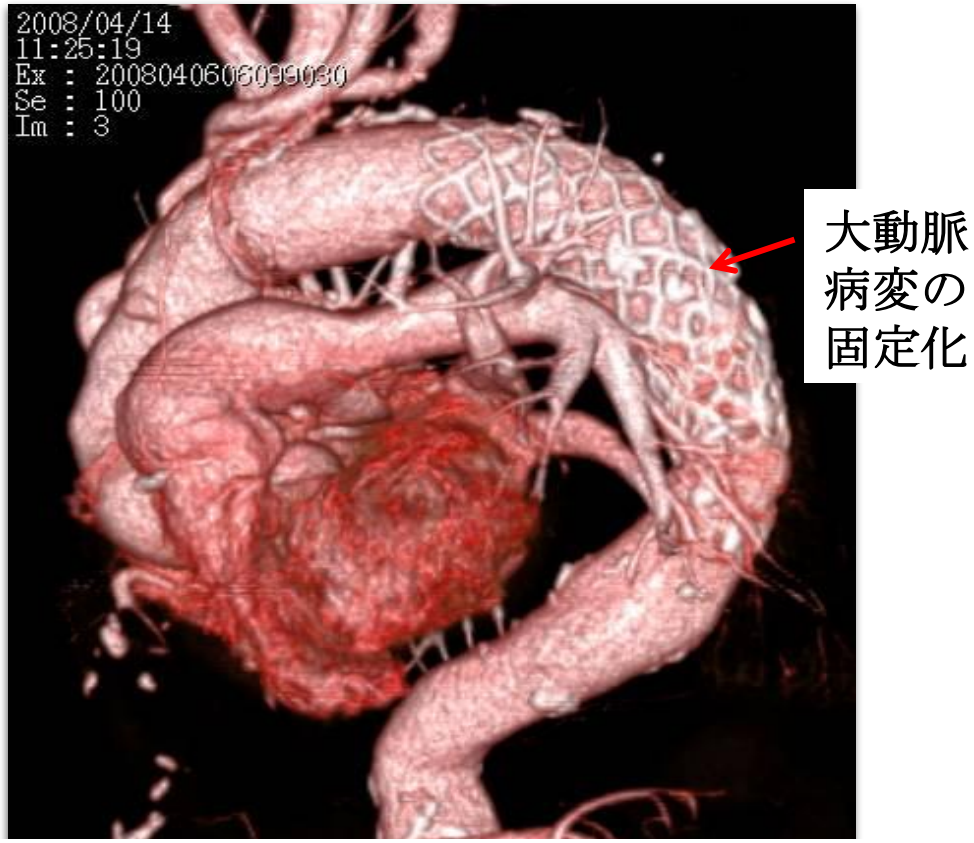




エレファントトランク法とFrozen エレファントトランク法の比較



エレファントトランク



Frozen エレファントトランク

分枝再建を目的とした
Fenestarated or Branched
endograft（ステント
グラフトの最初の臨床応用

Roy Greenberg
クリーブランド・クリニック

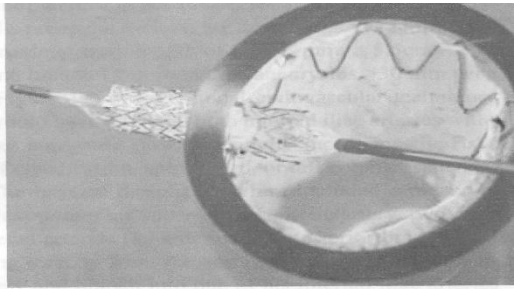
Endovascular aneurysm repair using branched or fenestrated devices

Roy K. Greenberg, M.D.
Director of Endovascular Research

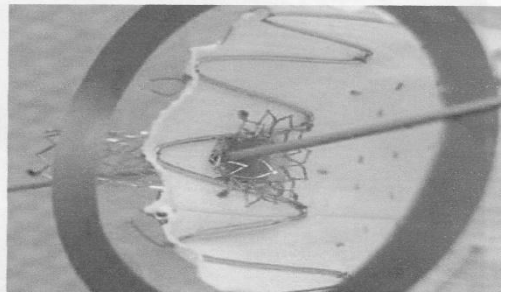
Departments of Vascular Surgery, Cardiothoracic Surgery, and Biomedical Engineering

The Cleveland Clinic Foundation.

J Vasc Surg 39:279-87, 2004



バルーン拡張後ステント留置



ステント流入部のフレアーによる固定

ステントグラフトの利点と問題点および今後の課題

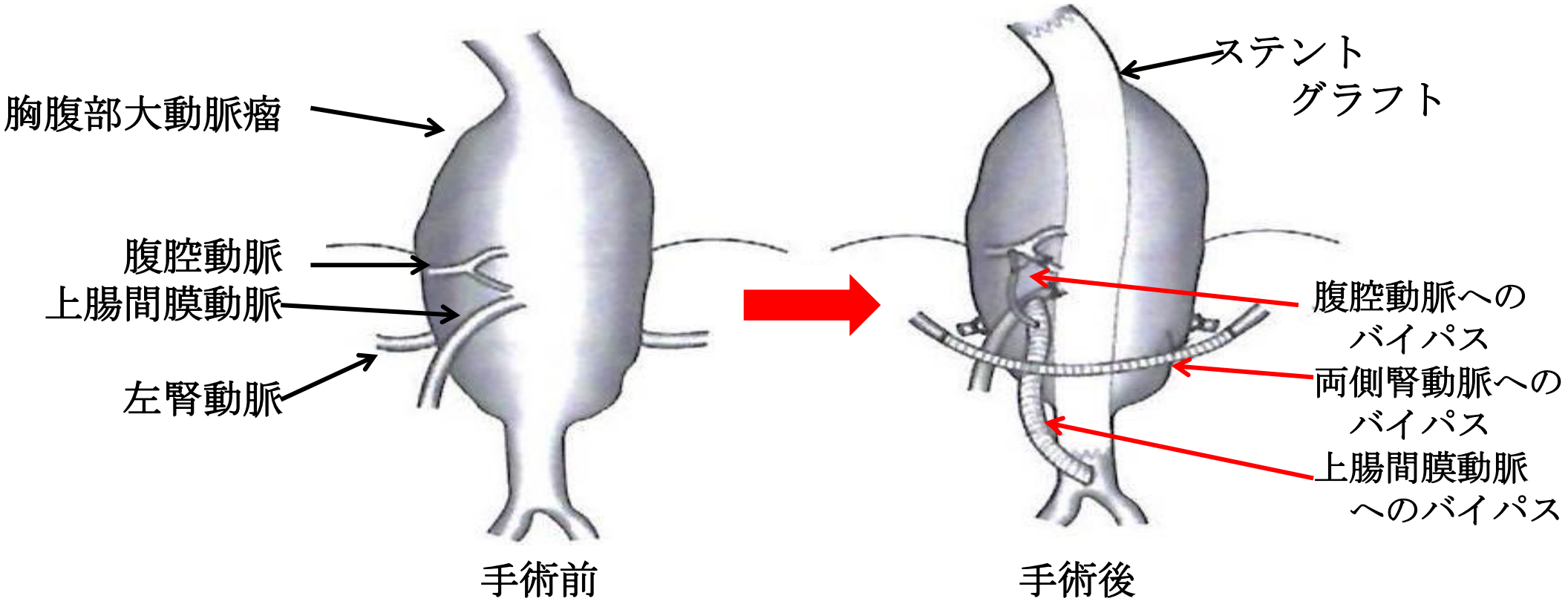
利　点

- 低浸襲である
- 出血量が少ない

問題点と今後の課題

- 適応が限定される（高度蛇行、複雑な分枝を伴う解離例）。
- ステントのまわりから血液が漏れることがある。
- 加齢とともに大動脈形態が変化を来たす可能性の高い若年者症例への適応

胸腹部大動脈瘤に対する
hybrid endovascular aortic repair



Kuratani T et al. Eur J Cardio-Thorac Surg. 2010

胸腹部大動脈瘤の治療法別成績の比較

報告者、報告年	手術法	症例数	死亡率（%）	脊髄障害発生率（%）	10年生存率（%）
Coselli JS, 2016	人工血管置換 Clamp and sew	3309	5.3	5.3	36.8
Eaglelon MJ, 2016	窓つき、また枝つきステントグラフトによる置換	354	3.5-7.0	1.8-7.8	
Kuratani T, 2010	腹部分枝へのバイパス後、ステントグラフトによる置換	86	2.3	1.2	66.6

大動脈瘤に対する外科的治療

1. 大動脈瘤に対する外科治療は患者と共に始まり、
   患者から学びながら発展してきた。

2. 手術成績は良好となってきているが、急性大動脈
   解離例の基部置換術の成績改善は今後の課題である。

3. 大動脈瘤治療チームとしての人工血管置換術と
   ステントグラフト内挿術の共存を図る必要がある。