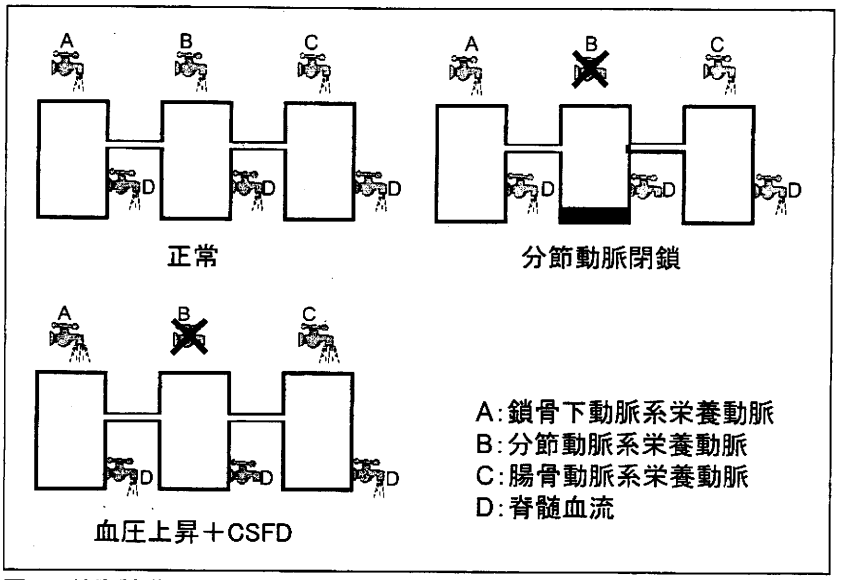

図2　前脊髄動脈の不連続性を加味した脊髄血流の模式図
前脊髄動脈は血行力学的には不連続な場合が多く，実際には血圧上昇とCSFD(脳脊髄液ドレナージ)を加えても，胸髄への血流供給は不十分となりうる．この模式図では，前脊髄動脈の血行力学的連続性を，3つの水槽を連結する管の高さで表現しうる．

に合流するものに2大別できるが，前者では合流部の尾側から頭側の脊髄への血流は期待できないことを，すでに1986年にSvenssonらが指摘している[21]．著者はMD-CTにてこの形態を把握し，術中脊髄虚血の機序を電気生理学的モニタリング結果から検討した[22]．この検討では，ヘアピン型動脈が単独で描出されたものでは半数が再建再灌流まで虚血はreverseできなかった一方で，トの字型や複数の栄養動脈が描出されたものでは分節動脈の逆流制御で虚血はすべてreverseできた．すなわち，トの字型の合流形態を有する場合，前脊髄動脈は血行動態的に頸髄から腰髄まで連続とみなすことができ，これを介する側副血流は，その供給源が鎖骨下動脈や内腸骨動脈であっても，有効に胸髄まで分布すると思われる．一方，ヘアピン型栄養動脈が単独で描出されたものは前脊髄動脈を介する側副血流は期待できず，脊髄血流が不十分となる場合が半数程度ある．こういった症例では**図1**に示したようなコンセプトは成立せず，**図2**のようなモデルを考える必要がある．

4. 小範囲分節遮断法

側副血行路には，前脊髄動脈を介するもののほかに，分節動脈間の吻合を介するものと脊柱管内外の細動脈を介するものがある．前者は近接する動脈からのものであれば低圧・定常流でも有効，後者は良好な拍動流が維持されている場合にかぎり有効と考えられる．

著者は，近接する分節動脈間の吻合を介する側副血流を最大限に生かしつつ血行再建を行うため，小範囲分節遮断法を提唱してきた[8]．これは，一度に遮断する分節動脈が2対以下の場合脊髄障害が発生しないという自験例の分析結果に基づくもので，2分節以下の小範囲遮断・分節動脈再建を繰り返すものである．この方法の妥当性を検証するため，小範囲分節遮断法導入前後で再建中の虚血発生頻度(ESCPを用いた)が減少したかどうかを検討したところ，小範囲遮断以前は85%に脊髄虚血が検出されたのに対し，導入後は46%に減少していた．対象を

広汎なCrawford I・II型に絞って再度検討したが，小範囲分節遮断：導入により脊髄虚血発生頻度は90%から27%に減少していた[23]．

5. 遅発性脊髄障害と分節動脈再建

分節動脈非再建時の脊髄障害の特徴は，遅発性障害が多いことである．Grieppらの最新の報告では遅発性障害が85%を占め[24]，TEVAR後の脊髄障害も遅発性障害がほとんどとされる．これは，側副血行路に依存した脊髄血流量がborderline rangeにあるため，術後の呼吸血行動態の悪化に弱いことが原因の一つと考えられている．ブタの分節動脈閉塞モデルでは，脊髄障害ブタでも術後の脊髄血流は減少していないが，非障害ブタにみられる72時間程度続くhyperemic responseがみられない[25]．このような観点から，遅発性脊髄障害の対策として，術後も高血圧管理とCSFDを72時間継続することが行われている．

一方，分節動脈再建を行った自験例では，遅発性障害例は経験していない．これは，再建により脊髄血流がより高いレベルに維持されたためと考えられる．Collateral network conceptは，分節動脈再建は不要であるという解釈をされることが多いが，側副血流を上手に生かせば虚血を作らずに分節動脈再建が可能という解釈も可能である．著者はこの立場に立ち，分節動脈再建は遅発性障害防止に有効と考え，側副血流を最大限に生かす小範囲分節遮断法を用いて分節動脈再建を行っている．

6. 脊髄栄養動脈の同定

古くは選択的血管造影が行われたが，それ自体に脊髄障害のリスクがあり普及しなかった．1980年代後半から，術中の電気生理学的モニタリングにより同定しようという試みがなされ，Laschingerらはsomatosensory evoked potential(SSEP)を用い[26]，われわれは硬膜外刺激，硬膜外導出によるevoked spinal cord potential(ESCP)を用いてきた[27]．しかし2000年代に入り，MRA[28]やMD-CT[29]を用いて術前に非侵襲的同定が可能となり，脊髄保護戦略も大きく変化した．著者はMD-CTを用いてきたが，再建する分節動脈とその手順は術前決定するよう戦略が変化し，再建数も栄養動脈とその前後あわせて2分節程度に減少した．

この戦略の妥当性を2007年，小範囲分節遮断法導入後の胸腹部大動脈置換自験例111例を対象として検討した．MD-CT非施行56例と施行55例の比較では，遮断分節数には差は認めないものの，再建分節数，特に，グラフト間置して個別に再建した分節動脈数が減少した．またMD-CTで栄養動脈を同定できた43例とできなかった12例の比較でも，同定できた例では閉鎖した分節動脈数が多かった．このような再建分節動脈数の減少にもかかわらず，術中のESCP変化の検出率にはまったく差はなく，新しい戦略は妥当と思われた．

7. 術中モニタリング

従前に栄養動脈が同定されるようになり，術中モニタリングの意義も，手術戦略およびその実施の妥当性の検証へと変化している．この状況下では，モニタリングにより側副血流が十分かを監視し，その結果に応じて灌流圧(中枢血圧，CSF圧)を調整するという点で，麻酔科医が果たす役割は非常に大きい．Stealの制御を含め，これらの条件を最適化しても脊髄虚血変化がreverseできない場合，選択的灌流が検討される．

モニタリング法にはSSEP，ESCPに加え，motor evoked potential(MEP)がある．SSEPは簡便であるが，感覚神経のモニタリングであり，末梢神経・脊髄・脳の影響を受け，麻酔薬や電気ノイズにも弱く，感受性，特異性ともに低い．1988年のCrawfordらによるprospective studyで，偽陰性13%，偽陽性67%という結果から脊髄障害防止に役立たないと結論された[30]ため広く普及はしていないが，簡便さからまだ使われている．

MEPは1990年代後半の経頭蓋電気刺激の導入[31]後急速に普及した．運動神経のモニタリングであり，簡便で感受性は高いが，脳・脊髄・末梢神経を反映

するため特異性が低い．またSSEP同様麻酔薬や電気ノイズに弱く，麻酔科の負担も大きい．このような背景を反映し，25～75%まで，施設によりさまざまなcut off値が用いられている．Okitaらは75%が最も有用性が高く，偽陰性0%，偽陽性2%と報告している[32]が，より鈍感な25～50%のcut off値を用いても，より高い偽陽性率を報告しているものが多い．SafiらはMEPはSSEPより多くの情報を与えないと結論している[33]．

著者らが用いてきたESCPは感覚神経のモニターと誤解されているが，実際には運動神経機能も反映する．2本の硬膜外電極を要するのが欠点であるが，脊髄のみの機能を反映するため，自験例では感受性，特異性ともに100%と非常に高い．ほかのモニターとは異なり，術後の神経機能とよい相関が得られるのも特徴である．著者は2009年，ESCPとMEPの相関をprospectiveに41例で比較した．MEPは経頭蓋刺激で，麻酔は筋弛緩非使用のTIVAとし，深度はBISレベル50%となるよう留意した．この結果，モニター試行41例中モニター可能はMEP 95%，ESCP 65%で，硬膜外電極留置の困難性が示された．一方，術中モニター変化（MEPでは非脊髄性変化を除外した）はMEP（cut off 75%）で20/39，MEP（cut off 50%）で15/39，ESCP 4/26で検出され，不一致8例はいずれもMEP変化のみが検出された．このうちMEP変化を一過性のstealで説明可能なものは4例で，残る4例は術中因子では説明不能であった．また最終変化と術後神経機能の相関を見ると，ESCPでは偽陰性・偽陽性はなかったが，MEPでは偽陽性が2例，50% cut off MEPでは偽陰性が1例みられた．後者は大腿・下腿筋のMMT（徒手筋力テスト）は4であったが，腰筋のMMT低下のため自立2足歩行は困難であった．

またMEPでは下肢虚血も反映されるため，このパターンを知っておく必要がある．著者の経験では，下肢虚血による変化は手術操作から変化までに時間がかかるのに対し，脊髄性は手術操作後速やかに変化する．また下肢虚血の場合，回復は遮断解除後すぐ始まるが，完全回復には時間を要する．以上，術中モニタリングはsteal，脊髄栄養動脈の遮断，下肢・脳虚血，脊髄灌流圧など，手術操作と併せて判断する必要があるが，著者の経験ではMEPの信頼性はESCPには及ばない．

8．薬理学的脊髄保護

脊髄保護目的で臨床使用されている薬剤には，ナロキソン，ステロイド，エダラボン，バルビツレート等がある．Opiate receptor antagonistであるナロキソンは，麻痺がナロキソンで軽快した症例の経験をきっかけとして1980年代後半にAcherらが使用を始め[34]，1994年にはCSFDとの組み合わせで脊髄障害が22%から2%に減少したと報告した[5]．その効果を疑問視する向きも多いが，著者らは脊髄障害例で上昇すると報告されているCSF中神経興奮性アミノ酸の分析で，ナロキソン投与例ではこれらが抑制されていることを報告した[35]．

このほかの薬剤では，高血糖の弊害が指摘されインスリンが用いられているほか，術後の鎮痛・鎮静ではデクスメデトミジンが有利であるとされる．大動脈遮断時の血圧管理に用いられる薬剤では，ニトログリセリンやニトロプルシドはCSF圧を上昇させ有害とされるが，PGE1やCa拮抗薬にはこの有害作用はみられない．

実験的には多数の薬剤が検討され，それぞれ保護効果が報告されている．特にNMDA拮抗薬は有望視されている．著者らも，ラザロイド，ニコランジル虚血前投与，FK506等の保護効果を報告してきた．しかし，いずれも虚血許容時間を劇的に延長するものではなく，apoptosisあるいはprogressive necrosisによる遅発性脊髄障害の抑制程度の効果であり，臨床的意義は不明である．

Ⅲ　胸腹部大動脈置換術の成績

現在まで著者は，MD-CTとMRAによる栄養動脈同定，軽度低体温DAP＋小範囲分節遮断＋

CSFD(または超低体温), ナロキソン, ESCP(MEP)モニタリングを基本戦略として胸腹部大動脈瘤の手術を行ってきた. この戦略による1995年8月から2010年3月まで150例の成績は, 30日死亡1例(Coselli公式予測値4.4例), 在院死亡6例, 脊髄障害8例(同予測値8.8例)であり, 日本胸部外科学会2008年国内集計559例の30日死亡10%より良好になっている. 脊髄障害のうち半数は, 分節動脈再建不能な感染性大動脈瘤破裂例であり, これを除くと脊髄障害は2.8%であった.

国内主要施設の現況を2009年の日本胸部外科学会シンポジウム抄録から見ると, 東北大学122例(10年)で在院死8%・脊髄障害5%, 国立循環器病センター123例(6年)で在院死11%・脊髄障害6%, 神戸大学112例(年数不明)で30日死亡8%・脊髄障害13%, 大阪大学(TEVAR)87例(12年)で30日死亡1%・1年大動脈event発生12%・脊髄障害0%であり, これが国内の現況と思われる.

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Aortic Surgery and Spinal Cord Protection
—Changes in the Concept and the Roles of Anesthesiologists—

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Spinal cord ischemia during aortic surgery has been thought to result from occlusion of the feeding artery that arises from the segmental artery. This concept has recently been challenged, and it is now believed that occlusion of all the segmental arteries does not result in spinal cord ischemia, if spinal cord perfusion pressure (mean arterial pressure-cerebrospinal fluid pressure) is maintained at a high level, thanks to the presence of a rich collateral network. In this concept, anesthesiologists play a major role by monitoring ischemia and optimizing spinal cord perfusion pressure.

In this article, I outline the strategies of spinal cord protection under the current concept and the role of anesthesiologists that surgeons expect. In addition, new insights are described for when the collateral blood flow fails to maintain the spinal cord viability. Operative results of my personal experience with thoracoabdominal aortic aneurysm repair are also presented.

Key Words : Thoracoabdominal aortic aneurysm, Spinal cord injury, Spinal cord feeding artery, Collateral blood flow

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特集 5

大血管手術の術後ケアと合併症対応

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key point

- 大動脈の待機手術は，「突然死を防ぐため無症状の患者をいかに機能損失なく回復させることができるか」という手術である．
- 最も注意すべきは中枢神経（脳・脊髄）合併症であり，術後はこの早期発見に努める．
- 術後せん妄は軽度の広汎な脳障害による高次脳機能低下のサインであり，ICU 環境や薬剤選択に注意する．
- 脊髄障害防止には脊髄灌流圧維持が重要で，血圧維持と脳脊髄液ドレナージの適切な管理が求められる．
- 弓部の手術では誤嚥に注意する．
- 開胸手術後では鎮痛・排痰を十分に行い，呼吸器合併症予防に努める．

はじめに

機能回復を通じて生命予後を改善する心臓手術とは異なり，大動脈の待機手術は「突然死を防ぐため無症状の患者をいかに機能損失なく回復させることができるか」という手術である．従って，後遺障害につながる合併症を回避すること，不幸にして発生した場合には早期発見・治療を通してこれを最小限にとどめることが肝要であり，術後ケアの果たす役割は大きい．また緊急手術においては，患者が急激な状況の変化についていくことができない場合も多く，精神面のケアも重要となる．

本稿では，大動脈疾患の病態と手術の概要，ならびに合併症回避のためのチームとして，看護師に期待されるものを概説する．

病態と手術適応

1．大動脈瘤

待機手術の適応は，1年破裂率と手術危険率を比較して決定される．前者を高くするものには，瘤径，高齢，慢性閉塞性肺疾患（chronic obstructive pulmonary disease；COPD)，痛み，形態（嚢状＞紡錘状)，成因（解離＞真性）などがある[1]．後者は瘤占拠部位（弓部・胸腹部はハイリスク)，手術施設に加え，種々の患者要因に影響される．一般論では，上行大動脈は55mm程度，そのほかの胸部・胸腹部大動脈は60mm程度，腹部大動脈は50mm程度を目安に手術が行われるが，マルファン症候群や大動脈二尖弁などの背景を有する疾患群は，より早く介入される．また，嚢状瘤は小さくても破裂するため，一定の大きさを有するものや形態変化がみられる場合は手術が勧められる．

1歩先のまめ知識

壁張力はラプラスの法則（張力＝血圧×瘤半径÷壁厚）で規定されるため，瘤径が大きいほど破裂しやすい．

1歩先のまめ知識

マルファン症候群とは，骨格系異常，水晶体偏位と心血管病変を来す常染色体性優性遺伝疾患である．無治療では，30歳前後で心血管病変死に至る．

2．大動脈解離

大動脈の内膜に亀裂が生じ，中膜に血液が入り込み，大動脈壁が2層に剝がれたものである．もともとの腔を真腔，壁内に新しくできた腔を偽腔（解離腔)，その境目を剝離内膜，血液が流入する内膜亀裂をエントリー，流出する亀裂をリエントリーと呼ぶ．急性（2週間以内）と慢性（2週間以降)，スタンフォード分類A型とB型に分類される．

1歩先のまめ知識

スタンフォード分類：上行大動脈に解離があるものがA型，ないものがB型である．

急性A型では1時間あたり1～3%，48時間で50%，1週間で80%が死に至るため，緊急手術が行われる．主な死因は心タンポナーデで，ほかに冠動脈灌流異常による心筋虚血や急性大動脈弁閉鎖不全による心不全がある．いずれも上行大動脈が解離しているために生じるものであり，救命のためには最低限，上行大動脈を修復（多くは人工血管置換）しなければならない．遠隔予後改善を目指して，弓部大動脈までを置換範囲に含める場合もある（特にマルファン症候群や，エントリーが弓部大動脈に存在する場合など)．

急性B型では通常降圧治療が行われるが，20%程度では破裂や重要臓器灌流異常による生命の危険が及び，緊急観血的治療を要する．慢性期に入った大動脈解離は，拡張瘤化した場合や合併症が生じた場合に観血的治療の対象となる．最近は，急性B型解離の早期慢性期にステントグラフト治療を行い，エントリーを閉鎖することで慢性期の瘤化を防ごうとする試みも行われている[2]．

一方，偽腔が発症後早期に血栓で閉塞する場合があり，偽腔開存型よりも予後が良いことが知られている．このため，急性A型でも偽腔閉塞型では保存的治療が選択される場合がある．

術式と合併症

人工血管置換手術とステントグラフト治療がある．前者では血流を遮断して人工血管を吻合

するため，虚血および塞栓から下流の臓器を守る対策が必要である．また，解離の場合，術中の真腔・偽腔の血行動態変化により分枝灌流異常が生じ，臓器障害を来す場合がある．

後者は傷が小さく血行遮断を要さないのが利点であるが，塞栓の危険は従来手術と同等以上にある．現在臨床導入されている器具は，主要な分枝がない腹部と胸部下行大動脈瘤が適応であり，遠位弓部や胸腹部大動脈瘤では，分枝にバイパスを加えたり（debranching），ステントグラフトに窓を開けたり（開窓型），枝を付ける（分岐型）試みが行われている．

以下，部位別・術式別に，特有の合併症を含め解説する．

1．大動脈基部置換術

大動脈弁輪拡張症など，バルサルバ洞に病変を来した場合に行われる．大動脈弁閉鎖不全（aortic regurgitation；AR）を合併することが多く，人工弁と人工血管がつながったcomposite graft（人工弁付き導管）を用い，冠動脈を人工血管に再縫着するベントール手術が標準術式である．しかし，弁逆流の原因は弁尖自体ではなくバルサルバ洞拡張であることが多いため，最近はreimplantation手術（David）やremodeling手術（Yacoub）など，弁温存大動脈基部置換手術も行われる．

2．上行・弓部大動脈置換術

胸骨正中切開で人工心肺を用いて行われる場合が多い．通常の開心術と異なる点は，循環を停止し大動脈を開放して吻合を行う場合，臓器虚血・再灌流障害を防ぐために低体温が必要なことである．中でも脳は虚血許容時間が短く，高次脳機能障害を回避するには20℃以下まで冷却したとしても，循環停止時間は25分未満にとどめる必要がある[3)]．このため，脳血管を最初に再建して虚血時間を短縮する方法（arch first）や，脳血管だけは人工心肺を用いて灌流する方法（選択的脳灌流法，脳分離体外循環法）が用いられている．静脈から血液を脳に送る方法（逆行性脳灌流法）も用いられるが，実際に脳毛細血管を通過する血流量は数％にとどまるため，塞栓子の除去・低温の維持が主な効果と考えられる[4)]．

低体温は，体外循環時間の延長から出血傾向や全身炎症反応を引き起こすため，手術侵襲を増加させ，長期ICU管理の原因となる場合もある．このため最近では，選択的脳灌流を用いて脳を保護する場合，冷却を28℃程度にとどめる試みが行われている[5)]．脳を除くと，このレベルの低体温でも，再建時間は許容範囲となる．

急性A型解離に対する手術では，エントリーの位置を確認し，手術により新たな内膜亀裂や重要臓器灌流異常が生じることを避けるため，大動脈を遮断せず（あるいは遮断解除して）超低体温で循環停止下に手術を行う．エントリーが有効に閉鎖されていない場合，術後も厳重な降圧管理を要する．

これらの手術で最も注意すべき合併症は，脳梗塞と一過性脳障害である．脳梗塞は，主に粥腫（じゅくしゅ）の塞栓により生じるが，その主因は人工心肺送血管のジェット血流が粥腫を遊離させること（タイヤにホースで水をかけると，泥が飛ぶ様子を想像するとよい）である．解離の場合には，分枝灌流異常が脳梗塞の原因となる場合もある．

また，一過性脳障害は，術後のせん妄として

現れる場合が多い．従来は良性のものと考えられてきたが，実は回復後も高次脳機能が低下していることが判明し，軽度の広汎な脳障害の形であると認識されている[3)]．これは脳保護が不十分であった場合に生じ，特に脳循環停止（逆行性脳灌流も含む）時間が25分を超えると増加する．

3．下行・胸腹部大動脈置換術

左開胸（＋後腹膜経路）で，遮断より末梢の大動脈を灌流しながら手術を行う場合が多いが，超低体温を用いる場合もある．抗凝固しながら肺を操作すると容易に肺出血を来し，呼吸不全の原因となる．また，腎・腸管・肝などの腹部臓器に加え，脊髄の虚血障害を来す可能性があり，この防止が最大の課題である．原因は分節動脈由来脊髄栄養動脈の血流遮断であるが，脊髄血流はほかにも鎖骨下動脈系，内腸骨動脈系から供給を受けており，これらを介する側副血流の維持が術中・術後とも重要になる[6)]．このため血圧を高めに維持し，脳脊髄液ドレナージを行う場合が多い．

1歩先のまめ知識

脊髄灌流圧は「平均動脈圧－脳脊髄圧」で規定されるため，脳脊髄圧を下げる目的で脳脊髄液ドレナージが行われる．

4．ステントグラフト内挿術

バネ（ステント）が付いた人工血管を下流の動脈から挿入して大動脈病変部の血管内で広げ，病変を中から覆う治療である．良い治療効果を得るためには，中枢と末梢に健常な圧着部分を十分長く確保することが重要である．

表1 せん妄と薬剤

<せん妄を誘発する可能性があるもの>
・ベンゾジアゼピン系睡眠薬
・麻薬
・プロポフォール（全身麻酔薬）
<せん妄の治療に有用なもの>
・セレネース®（ハロペリドール） →錐体外路症状，悪性症候群，QT延長に注意
・セロクエル®（クエチアピンフマル酸塩） →催眠作用あり，血糖上昇に注意
・リスパダール®（リスペリドン） →粘膜からも吸収，催眠作用弱い
・プレセデックス®（デクスメデトミジン塩酸塩） →開心術後のせん妄抑制の報告あり

合併症としては，血管内操作に伴う塞栓症，分枝動脈閉塞による臓器障害（脊髄など），太いカテーテルシースによる血管損傷に加え，瘤内への血流の漏れ（endoleak：エンドリーク）やステントグラフトの移動など，特有なものがある．後2者は治療効果を失わせる可能性もあり，注意が必要である．

1歩先のまめ知識

endoleak（エンドリーク）：中枢・末梢から（タイプⅠ），分枝逆流（タイプⅡ），ステントグラフト継ぎ目から（タイプⅢ），人工血管布の漏れ（タイプⅣ）に分類される．

術後管理と看護師の役割

術後管理の多くは通常の開心術と同様であるが，大血管手術では，まず中枢神経障害の有無を確認する必要がある．このため，術後特別な意味なく鎮静を開始することは厳に慎まなければならない．覚醒し，神経学的異常がないことを確認できれば，必要に応じて鎮静を開始してよいが，出血がなく呼吸循環動態に異常がなけ

ればこの時点で抜管するのが普通である．なお，鎮静薬を使用する場合，できれば神経細胞保護的に働くもの，せん妄を引き起こしにくいものを選択する（p.40 表1）．

以下，部位別・術式別に管理の要点を述べる．

1．大動脈基部置換術

大動脈弁手術と冠動脈再建手術の同時手術と同様の術後管理を行う．すなわち，心筋虚血の発生を監視し，機械弁を用いたベントール手術では適宜抗凝固を開始する．弁温存手術の場合，弁逆流が残存している可能性があり，その有無と程度を把握し，聴診所見や拡張期血圧などから，その推移を観察する．

2．上行・弓部大動脈置換術

脳合併症を早期に発見することが重要である．覚醒遅延や痙攣がみられたら，脳梗塞の有無を確認するため画像診断を行い，速やかに治療を開始する．

術後せん妄は，挿管中であっても観察により診断可能である．昼夜のリズムを作り，夜間は熟眠できるよう努めるが，中途半端な量のベンゾジアゼピン系睡眠薬はせん妄を増悪させるので注意が必要である．通常，抗精神病薬であるmajor tranquilizer（メジャートランキライザー）で対処する．昼間はご家族などのよく知った顔に触れてもらうとよい．

経口摂取開始に際しては誤嚥に注意する．弓部の手術では左反回神経麻痺が発生し得るため，声がかれている場合は経口摂取開始を慎重に行う．高齢者ではもともと嚥下機能が落ちており，軽度の嗄声でも誤嚥しやすい．さらに，脳機能低下も嚥下機能を悪化させる．誤嚥が見られる場合，積極的に嚥下機能評価を依頼し，リハビリテーションを開始する．水分は誤嚥しやすいため，とろみをつける．

3．下行・胸腹部大動脈置換術

脊髄障害と呼吸器合併症予防が重要である．前者のため留置された脳脊髄液ドレーンは，頭蓋内出血，髄膜炎，チューブ断裂，血腫，髄液瘻などの合併症の可能性があり，適切な管理が必要である（図1）．特に頭蓋内出血はドレナージ量や速度が大きいと発生しやすいとされ，圧10mmHg以上[7]，速度15mL/h以下[8]が推奨されており，これを逸脱しないよう，また排液が血性にならないか観察が必要である．さらに脊髄障害発生時には，ドレナージが有効に機能しているかどうか，直ちに確認する．

呼吸器合併症予防には創痛の管理が重要であり，筆者らは肋間神経の持続ブロックを術後早期に行っている（図2）．十分な喀痰排出ができ，かつ過度の鎮静にならないよう，鎮痛薬を適宜使用しつつ，排痰の補助を行う．

4．ステントグラフト内挿術

特有の合併症に注意する．塞栓症は術中に気付かれない場合も多く，分枝閉塞は術後に発生する場合もある．これらは中枢神経障害に加え，肝・腎・腸管などの腹部臓器障害を来し得るが，特に腸管虚血はしばしば診断困難で致命的であり，患者の自覚症状（腹痛）の把握が早期発見には最も重要である．ステントグラフト治療では分節動脈再建は行われないため，脊髄障害（特に遅発性障害）防止の観点では，脳脊髄液ドレナージなど術後の脊髄灌流圧維持は特に重要である．また，エンドリークにより治療効果が得

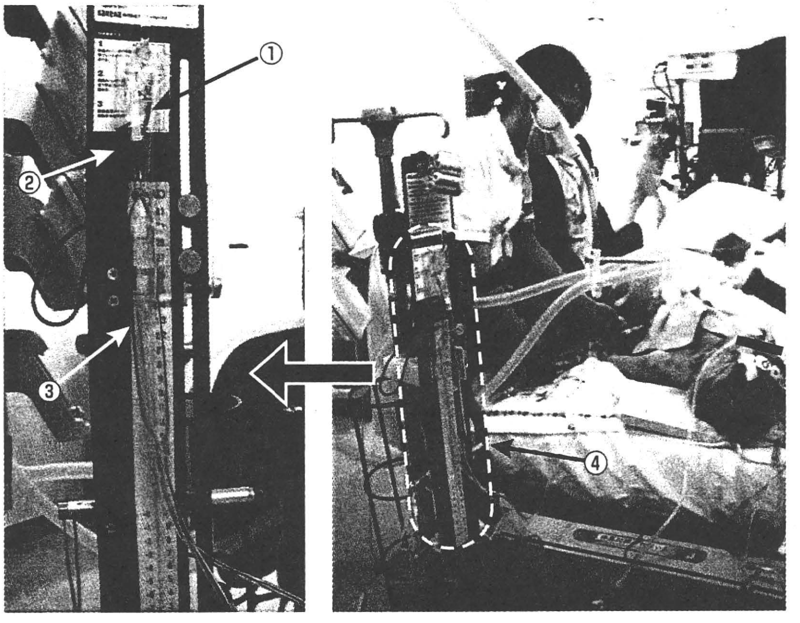

図 1 脳脊髄液ドレナージの管理

①フィルターは濡れていないか，②クランプを外したか，③円盤の高さは設定値か（この図では 13cmH_2O=10mmHg），④基準点は外耳孔の高さか，の４点をチェックする

られていないことがあるため，情報を共有して管理することが重要である．

おわりに

看護師は，患者に発生し得る合併症のサインに最も早く気付くことができる職種である．と同時に，身体的・精神的ケアを通じてさまざまな合併症を予防する第一線の役割を担っている．外科医がカバーしきれない，これらの役割にチームとして期待されるものは大きく，本稿がその一助になれば幸いである．

図 2 創痛の管理

胸膜外に留置した肋間神経ブロック用のチューブに局所麻酔薬を持続注入している．大血管手術では抗凝固を行うため，通常硬膜外チューブは留置しない．また，硬膜外は血圧低下の原因となることがあり，脊髄灌流圧低下から遅発性脊髄障害の原因ともなり得るので不利である

COLUMN

術後ケアこそナースが力を発揮する

私たち外科医は，手術適応を慎重に判断し，知識・経験に基づき適切な術式・補助手段を選択し，その遂行に最善を尽くすが，それでも一定の確率で合併症は発生する．不幸にして合併症が発生した場合，何とか被害を最小限にとどめ，社会復帰できるよう努力するのはもちろんであるが，そのためには早期発見による迅速な対処が必要になる．また，状態の変化に動揺する患者・家族への精神的サポートも必要になる．順調に終了した手術であっても術後に合併症を来すこともあり，良好な結果を得るためには，この防止も大きなウェイトを占めている．外科医は常に患者のベッドサイドにいられるわけではないので，これらはチームとして共に診療に当たっている看護師の皆さんの力に負うところが大きい．

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Long-term results of hybrid endovascular repair for thoraco-abdominal aortic aneurysms☆

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Abstract

Objective: The treatment of thoraco-abdominal aortic aneurysms (TAAAs) is extremely laborious, due to the surgical complexity of this condition. In particular, postoperative spinal paraplegia poses a severe complication that significantly lowers patient's quality of life. In 1997, we devised a hybrid procedure consisting of extended endovascular aortic repair (EVAR) and visceral reconstruction. In this article, we report the long-term results obtained from this procedure. **Methods:** We conducted 1106 endovascular aortic repairs between 1997 and 2008. Among these, we selected 86 cases of TAAA. The mean patient age was 71.6 years. Preoperative complications included 19 cases of stroke, 22 cases of coronary artery disease (CAD) and 16 cases of chronic obstructive pulmonary disease (COPD). Cerebrospinal fluid drainage was initiated during the operation. We performed bypasses from the aortic bifurcation to abdominal visceral arteries, and deployed stent grafts to exclude the entire TAAA. **Results:** Operative time averaged 386 min. We lost two patients and encountered only one case of graft occlusion. Two patients had acute renal failure, but neither required a tracheostomy. Furthermore, no patients exhibited paraplegia or delayed paraplegia. We observed endoleaks in nine cases, and shrunken aneurysms in 73 cases. Long-term results included survival rates of 94.8%, 85.8%, 80.2% and 66.6% at 2, 5, 8 and 10 years, respectively. Only two patients died from aortic events. Rates of freedom from aortic events were 90.7%, 80.6%, 70.8% and 70.8% at 2, 5, 8 and 10 years, respectively. **Conclusions:** The hybrid TAAA-repair protocol yielded satisfactory results. Although thorough follow-up is required for visceral bypass, this procedure could become the standard for TAAAs.

Keywords: Endovascular aortic repair; Hybrid procedure; Long-term results; Postoperative paraplegia; Thoraco-abdominal aortic aneurysm

1. Introduction

The treatment of thoraco-abdominal aortic aneurysms (TAAAs) is extremely laborious, as these aneurysms are complex and require invasive surgery [1–3]. Data from the Nationwide Inpatient Sample (NIS) database in the United States suggest a mortality rate approaching 22.3% [4]. In addition, devastating complications, postoperative paraplegia in particular, significantly lower postoperative patient quality of life (QOL). Despite refinements in surgical techniques for spinal protection, risk of postoperative neurological deficit remains high [1–4]. Although there is a considerable risk in patients with significant co-morbidity, conventional surgery remains an option because the mortality rate for conservative treatment at 2 years is ~76% [5].

Surgical treatments for thoracic aortic aneurysms have recently shifted to endovascular aortic repair because it is less invasive and improves postoperative QOL. In addition, the incidence of postoperative paraplegia in endovascular aortic repair for thoracic aortic aneurysms has decreased extremely [6–8]. In an attempt to prevent paraplegia, we developed a hybrid TAAA repair in 1997, consisting of abdominal visceral reconstruction and extended endovascular aortic repair. Early favourable outcomes encouraged another group to perform this procedure in patients suitable for this surgery as well [9–11]; however, the long-term results of their study have not been reported.

In the present study, we evaluated the early and long-term results obtained from this procedure in our single-centre experiment.

2. Patients and methods

From January 1993 to July 2009, we performed thoracic endovascular aortic repair (TEVAR) in 1050 of a total of 1458 thoracic and thoraco-abdominal aortic surgeries. Of these 1050 cases of TEVAR, 86 patients with TAAA underwent TEVAR with the reconstruction of abdominal visceral arteries in a

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Table 1
Patient's demographics and aortic characteristics.

Patients	86
Mean age (range)	71.6 years (47—86)
Gender ratio (male/female)	62/24
Mean aneurysmal size (range)	65 cm (55—88)
Aortic pathologies	
Degenerative aortic disease	55
Chronic aortic dissection (Marfan syndrome)	31 (3)
Crawford classification (modified)	
Type I (%)	15 (17.4%)
Type II	8 (9.3%)
Type III	31 (36.0%)
Type IV	11 (12.8%)
Type V	21 (24.4%)

procedure named the hybrid TAAA repair (mean age of patients: 71.6 years; range: 47—86 years; and 62 (72.1%) patients were male). With the exception of infectious TAAAs, we performed this hybrid procedure for almost all patients who were referred to our hospital during this period. Aortic pathologies included 55 degenerative aneurysms and 31 chronic aortic dissections, and three patients had Marfan syndrome. Aneurysms were classified according to the modified Crawford classification: type I ($n = 15$), type II ($n = 8$), type III ($n = 31$), type IV ($n = 11$) and type V ($n = 21$); type III TAAA was the most common (36% of patients). Median TAAA maximum diameter on the short-axis image was 65 mm (range: 55—88 mm; Table 1). Elective operations were performed in 76 cases (88.4%), and urgent operations were performed in eight patients who were symptomatic but had no radiographic evidence of rupture. The remaining two cases had radiographic evidence of rupture. These patients were high-risk cases with preoperative co-morbidity. Cerebrospinal disorders were present in 19 cases (22.1%), coronary artery disease in 22 cases (25.6%), chronic obstructive pulmonary disease (COPD) in 16 cases (18.6%), a histology of thoracotomy in 18 cases (20.9%) and a history of previous cardiovascular surgery in 29 cases (33.7% cardiac surgery, $n = 7$; ascending, $n = 4$; aortic arch, $n = 3$; descending, $n = 8$; thoraco-abdominal, $n = 2$; and abdominal, $n = 5$; Table 2). In all cases, a 64-row multi-slice computed tomography (CT) was performed for planning and sizing.

Anatomical inclusion criteria for this procedure were as follows: length of proximal and distal landing zone longer than 20 mm, aortic neck diameter of 18—42 mm and absence of circumferential thrombus and the possibility of a visceral artery de-branching. Patients were evaluated by postoperative contrast CT scans at 1, 6 and 12 months, and annually thereafter.

Table 2
Preoperative patient profiles.

Coronary artery disease (%)	22 (25.6%)
Cerebrospinal disorder	19 (22.1%)
Chronic obstructive pulmonary disease	16 (18.6%)
History of thracotomy	18 (20.9%)
History of previous cardiovascular disease	29 (33.7%)
Cardiac surgery	7
Vascular surgery	22
Ascending	4
Aortic arch	3
Descending	8
Thoraco-abdominal	2
Abdominal	5

2.1. Operative procedure

Prior to the procedure, we created cross-shaped bypass grafts with a 12-mm woven graft and an 8-mm polytetrafluorpethylene (PTFE) graft. Procedures were performed under general anaesthesia in an operating room. Following laparotomy, a coeliac artery, a superior mesenteric artery, bilateral renal arteries and the inflow site of bypassing were exposed. Bypass grafts were then constructed from the aortic bifurcation or common iliac artery to the superior mesenteric artery and bilateral renal arteries. The choice of the inflow site was based on the extent of TAAA, whether or not prior abdominal aortic repair had been performed and the quality of the walls of the native aorta and iliac arteries.

Next, side-to-end anastomoses were created by suturing the 12-mm woven graft to a superior mesenteric artery from the inflow site, and end-to-end anastomoses were created by suturing bilateral renal arteries with 8-mm PTFE grafts anastomosed to the woven graft. Finally, side-to-end anastomoses were created by connecting a saphenous vein graft to a coeliac artery with ante-pancreatic graft routing. When we confirmed good collateral circulation from the superior mesenteric artery to the coeliac artery, we occluded the coeliac artery. Grafts were covered with retroperitoneal soft tissue at the end of all procedures (Fig. 1).

We then proceeded to the TEVAR procedure. Shin incisions were made in both groins and both femoral arteries were exposed for stent-graft delivery and aortic fluoroscopy. We used a common iliac artery for the retroperitoneal approach when the femoral artery was too small for sheath insertion. The device-deployment procedure was the same for each device system. When the size discrepancy between proximal and distal sites of the landing zone was at least 120%, tapered devices were used (e.g., home-made devices or the Talent Thoracic Tapered Stent Graft). In almost all cases, TEVAR was performed on the day after the bypass procedure.

The absence of endoleaks and good patency of visceral bypasses were assessed by completion aortography after deployment of the stent-grafts in all cases.

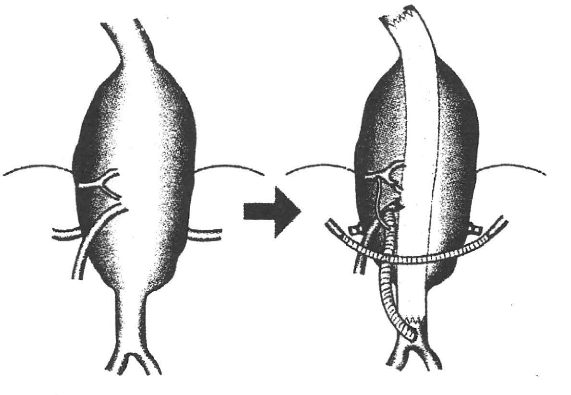

Fig. 1. The procedure of hybrid endovascular aortic repair for thoraco-abdominal aortic aneurysms (see text).

For spinal cord protection, cerebrospinal fluid drainage and a dose of naloxone were initiated during the operation and continued for 24 and 72 h after surgery, respectively, in all cases. Cerebrospinal fluid was allowed to drain freely with gravity with a target pressure of 10 mmHg.

2.2. Statistical analysis

All data were analysed retrospectively. Continuous variables were expressed as mean + standard deviation and categorical variables as percentages. Survival and freedom from aortic events were estimated by the Kaplan–Meier method. Data analysis was performed using the Statistical Package of Social Sciences version 11 (SPSS 11.0) for Windows (SPSS Inc. Chicago, IL, USA).

3. Results

3.1. Procedural results

In 11 cases (including two cases of rupture), operations were performed simultaneously, and 75 patients received staged operations. In staged operations, the mean interval between bypass and TEVAR was 1.2 days (range: 1–6 days).

A total of 304 visceral artery bypasses were performed (56 to the coeliac artery, 86 to the superior mesenteric artery and 83 to bilateral renal arteries). Mean number of bypass grafts was 3.6. A total of 49 patients received a quadruple bypass involving all abdominal visceral arteries, 34 received a triple bypass and three received a double bypass. Bypass to the coeliac artery was not performed in 34 cases. The coeliac artery was shown to be occluded in preoperative CT scans in nine cases. In 25 cases, we verified good collateral circulation from the superior mesenteric artery to the coeliac artery, so we occluded the coeliac artery during surgery by ligation ($n = 6$) or by coiling before the operation ($n = 19$) (Table 3).

For the present study, we used home-made devices (thin-walled polyester grafts and stainless-steel Z stents) in 75 cases, TAG thoracic endoprostheses (WL Gore & Associates, Phoenix, AZ, USA) in 10 cases and the Talent Thoracic Stent Graft (Medtronic, Minneapolis, USA) in one case (mean number of devices used: 2.4). In 27 cases, we used tapered devices (home-made devices, $n = 26$: Talent devices, $n = 1$).

Mean operative time was 382 min (reconstruction of visceral arteries: 259 min; TEVAR: 123 min). The access vessels for TEVAR were the common femoral artery ($n = 75$), iliac artery ($n = 9$) and aortic prosthetic grafts ($n = 2$).

Table 3
Visceral artery bypass of the hybrid TAAA repair.

Total amount of visceral bypass grafts	304
Target vessels	
Coeliac artery	56
Superior mesenteric artery	86
Left renal artery	83
Right renal artery	83
Mean number of bypass grafts	3.6
Quadruple bypass (coeliac, SMA, bil. renal)	49
Triple bypass (SMA, bil. renal)	34
Two bypass (coeliac, SMA)	3

TAAA, thoraco-abdominal aortic aneurysm.

Intra-operative type I endoleaks were detected in four cases, so we treated these with Palmatz XL (Cordis Co., New Brunswick, NJ, USA), and endoleaks were eliminated in all cases.

3.2. Early results

Procedural success was achieved in all cases. Two patients (2.3%) died within 30 days of the operations, one due to bowel necrosis by a thrombus and the other due to sepsis from cholecystic necrosis. Shaggy aortae were detected by preoperative CT scan in both cases. No patient deaths occurred prior to discharge from our hospital.

Postoperative complications included minor brain infarction ($n = 1$), acute renal failure without haemodialysis ($n = 2$), prolonged ileus (>7 days, $n = 3$) and one graft to the renal artery was occluded at 2 months following surgery, however, the patient's other kidney remained well preserved with a functioning graft, and no further intervention was pursued. In this study, we observed no incidences of paraplegia and one case of transient paraparesis, and all patients were discharged after achieving independent gait. Median duration of hospital stay was 26 days (range: 14–69 days).

Nine endoleaks (10.5%) were detected by CT scan at the time of discharge. Type II endoleaks were observed in five cases. Back-flow from a superior mesenteric artery to the aneurysm occurred in two of these cases due to loose ligation of a superior mesenteric artery, and intervention with coiling was performed successfully. The other three patients were followed with CT scan. Type I distal endoleaks occurred in two cases; these were successfully treated by additional intervention with Palmaz XL stents. Type III endoleaks were found in two cases; one patient underwent additional TEVAR, and one patient was treated with a balloon at the site of the leak. Both type III endoleaks were eliminated with these interventions (Table 4).

We detected an Adamkiewicz artery in 25 patients within the last several years using a 320-row multi-detector CT; 23 of these were detected prior to surgery. All arteries were shown to be occluded by TEVAR by postoperative CT scan and no incidence of postoperative paraplegia occurred in any of the 23 cases.

3.3. Long-term results

Aneurysmal size was determined by follow-up CT scan (mean follow-up time: 88.5 months; follow-up completion rate: 98.8%). All-cause survival rate was 94.8% at 2 years,

Table 4
Early results of the hybrid TAAA repair.

30 days mortality	2.3% (2/86)
Postoperative complications	
Renal failure (%)	2 (2.3%)
Prolonged ileus	3 (3.5%)
Graft occlusion	1 (1.2%)
Paraplegia	0
Paraparesis (transient)	1 (1.2%)
Endoleak	9 (10.5%)
Migration	0

TAAA, thoraco-abdominal aortic aneurysm.

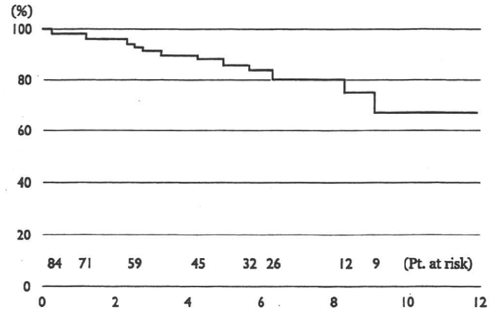

Fig. 2. All-cause survival rate; 94.8% at 2 years, 85.8% at 5 years, 80.2% at 8 years, and 66.6% at 10 years.

85.8% at 5 years, 80.2% at 8 years and 66.6% at 10 years (Fig. 2). Only two patients died due to aortic events; one patient experienced graft occlusion of a superior mesenteric artery resulting in fatal mesenteric necrosis, and the other patient experienced graft infection due to a duodenal fistula. We performed emergency resection of the duodenum and the graft, but this patient died due to multi-organ failure.

Freedom rate from aortic events was 90.7% at 2 years, 80.6% at 5 years, 70.8% at 8 years and 70.8% at 10 years (Fig. 3). Three patients underwent operations for other aneurysms (iliac aneurysm, $n = 2$; annulo-aortic ectasia, $n = 1$). We detected new endoleaks in five patients during follow-up; one patient experienced a type I distal endoleak 3 years after the operation, which was successfully treated by intervention with Palmatz XL stent, and two patients experienced type III endoleaks due to stent-graft migration after 2 years and 3 years. Both patients underwent additional TEVAR and these endoleaks were eliminated. We identified type II endoleaks in two patients during follow-up. Both patients were followed with CT scan because the size of the aneurysms did not change.

In the latest CT findings, short-axis imaging of aneurysms demonstrated shrinkage in 73 cases, no change in 11 cases and enlargement in two cases. As we were unable to detect any type of endoleak in the two cases with enlargement, both cases have been followed intensively with CT scans.

4. Discussion

Surgical treatments have recently shifted to minimally invasive procedures to improve postoperative QOL. As pioneers of this procedure, we have achieved solid results in endovascular aortic repair with stent-grafts since 1993 [12]. Postoperative paraplegia after endovascular repair for inferior thoracic aneurysms has been considerably reduced in our experience. We have, therefore, developed a new procedure, which allows for reconstruction of visceral arteries followed by TEVAR to cover the entire aneurysm.

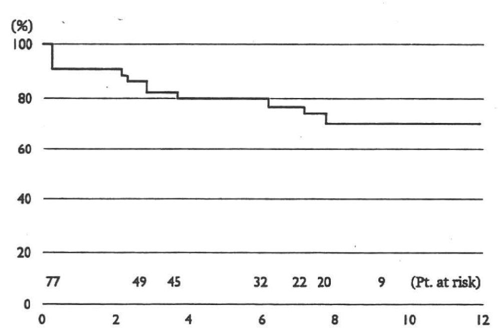

Fig. 3. Freedom rate from aortic events; 90.7% at 2 years, 80.6% at 5 years, 70.8% at 8 years, and 70.8 at 10 years.

The present study obtained excellent early and long-term results. All-cause survival rate was 80.2% at 8 years, and 66.6% at 10 years, which is significantly higher than rates observed following conventional surgical procedures. One reason for our good results was our follow-up system. For long-term follow-up, all patients received CT scans once every year to prevent serious issues such as aortic rupture due to stent-migration or endoleaks. Freedom from aortic-related events was 70.8% both at 8 and 10 years, due to migrations and endoleaks that are specific complications of endovascular repair. We identified five new endoleaks, three of which required critical attention. These patients could have died had we not detected the endoleaks by CT scan.

Graft patency is the most important factor for obtaining good long-term results from this procedure. In the long-term, only two patients died due to graft problems. We achieved excellent graft patency of bypassing to visceral arteries, which represented good long-term results Encouraging patency rates of 90–95% at 3 years have been reported in some series of bypass grafting for chronic mesenteric ischaemia and treatment of renal artery stenosis [13,14]. However, the safety and durability of retrograde bypass grafting have remained controversial. Kansal et al. [15] reported no difference in patency between antegrade and retrograde grafts in this later series.

Attainment of satisfactory patency for bypassing as well as excellent long-term results depends on the management of graft bypassing. The following three key points are recommended as ways to obtain good bypass patency.

(1) Bypass-graft shape

We created a cross-shaped graft for visceral bypassing, as described in Fig. 1. The bypass technique with this was simple and required a short operative time due to the few sites for anastomoses. In addition, graft lengths were short, especially in renal arteries.

(2) Selection of bypass-inflow sites

The appropriate choice of inflow sites is very important for excellent long-term graft patency. Prosthetic grafts are thought to be the best inflow sites for the visceral bypass to avoid sutures on the atherosclerotic native arterial wall and emboli from shaggy aortas [16]. We, therefore, performed graft replacement of abdominal aortas in 32 cases even when aneurysms were small. When the common iliac artery was used for the graft inflow, we also performed graft replacement to attain the ideal inflow.

(3) Bypass-graft route

Bypass-graft routes must also be selected carefully; we had a patient with a duodenal fistula. After experiencing this complication, we have tried to maintain separation of the grafts from the gastrointestinal tract by covering grafts with retroperitoneal soft tissue [16]. Visceral grafts require close monitoring to reduce the risk of late enteric erosion or fistula in their extra-anatomic route.

The most significant advantage of this procedure is the extremely low incidence of postoperative paraplegia. We had only one patient with transient paraparesis on the day following surgery from hypotension due to paroxysmal atrial fibrillation; by maintaining increased blood pressure, this patient recovered completely. According to a report from Griepp and Griepp [17], the spinal cord has high collateral circulation and a collateral network. Therefore, if we occlude several intercostal arteries, spinal cord ischaemia may not occur immediately. In addition, some believe that reconstruction of the Adamkiewicz artery may be important to prevent postoperative paraplegia. However, Adamkiewicz arteries were detected by preoperative CT in 22 cases occluded by TEVAR in the present study, and there was no incidence of postoperative paraplegia in these cases. Thus, the necessity for reconstruction of intercostal arteries for TAAA repair should be reconsidered.

Some studies have reported a 'steal phenomenon', which describes back-flow from intercostal arteries in the aorta where the aorta was dissected between the aortic clamping for the graft replacement of an aortic aneurysm [17–19]. Some studies reported that postoperative paraplegia was not common when conventional surgery for thoracic descending aneurysm was performed after ligation of the intercostal arteries in the operative lesion [19,20]; this procedure may prevent the steal phenomenon in cases where conventional TAAA surgery surgeries are performed. Thus, it is not difficult to understand how the rate of postoperative paraplegia is reduced due to the absence of the steal phenomenon in TEVAR.

The choice of simultaneous or staged procedures is an issue in hybrid TAAA repair and is made according to the specific clinical situation of each case. The staged strategy reduces operative invasiveness and postoperative complications, but as the interval between the bypass operation and TEVAR is extended. The risk of rupture may increase. In our treatment strategy, we use a staged operation, and TEVAR is performed on the day after re-vascularisation of visceral arteries.

Although we have achieved satisfactory early and long-term results for the hybrid TAAA repair, this procedure is not appropriate for all TAAAs. Additional long-term results are needed prior to use of this surgery in young patients. A branched device is strongly desired in the endovascular field [21,22]; if a branched device is approved for TAAAs, surgery to treat TAAAs will shift to simple TEVAR with branched devices. In the meantime, this hybrid procedure with TEVAR may become one of the standard procedures.

5. Conclusion

We have obtained satisfactory early results for hybrid TAAA repair; in particular, the complete lack of postoperative paraplegia strongly encourages us to use this procedure without hesitation. In the long term, the rate of aortic event-related death was extremely low. There were more than a few aortic events, especially specific complications related to endovascular repair, such as migrations and endoleaks; these patients required follow-up CT scans at regular intervals.

Based on our early and long-term results, we conclude that the hybrid TAAA repair may become one of the standard surgeries for TAAAs in high-risk patients although sufficient follow-up is needed for visceral bypass.

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Appendix A. Conference discussion

Dr M. Grimm *(Vienna, Austria)*: The results are very impressive and in contrast to the currently available literature reporting these small results in this combined approach. As a consequence, I feel that it is important to work out factors that are perhaps responsible for this difference to the current literature with your results.

In the current literature, most of the reports are dealing with Caucasian people suffering from obesity, they are suffering from COPD, so surgical exposure during the initial procedure seems to be more problematic than in people from Asia, as we know that these people are smaller. Do you think, this is my first question, that the smaller body surface area or body mass index of Japanese people maybe makes it technically simpler as compared to Caucasian patients?

The second question is: These are truly very excellent results. Nevertheless when comparing it with results of the surgical repair of a thoracoabdominal replacement of the aorta, don't you think that the higher need of repeated investigations by CT scans may be problematic for the patient and also more costly?

And the third question is: Could you be so kind as to give us a definition. What is a high-risk patient in your cohort and what is a low-risk patient? And do low-risk patients go into conventional surgery?

Dr Kuratani: All of the Japanese patients are, as you say, very small and the Asian people are the same. But usually it is better to expose the artery or the anastomosis. The Japanese people and the Asian people have a very low rate of diabetes or hypertension, so the aorta and also the artery are good. It is better in such a small surface patient, it is better to use this operation.

And as to cost, there are many cities in Japan, and there is a difference in the insurance compared to Europe and the USA. But I think that the cost is higher than the conventional operation, because there are many CT scans and checking is a need in the difficult patient. So maybe the cost is higher. And so we selected only the high-risk patients. For the low-risk patients, it is better to do the conventional operation. Maybe the risk is maybe the same.

Dr Grimm: Could you just briefly give us an impression, what is high risk? What are risk factors that turn people into high-risk or low-risk groups in your series?

Dr Kuratani: The high-risk series, high risk is okay.

Dr G. Wheatley *(Phoenix, Arizona, USA)*: Why did you choose a saphenous vein graft to the coeliac artery versus PTFE?

Dr Kuratani: Before we used a PTFE graft. In one case we had intestine and also a gastric fistula occurring with this PTFE graft, so that we changed it to the saphenous vein graft. After the changing, we have no problem with this graft.

Dr J. Bachet *(Abu Dhabi, United Arab Emirates)*: I'm very impressed by the number of patients that you find in your experience, 86 patients of this kind is an important number. I have no experience in this matter, so my question should be irrelevant. But, as I observe, it is heavy surgery. So to repeat what the previous discussant said, how did you define what are high-risk patients and not high-risk patients?

And a subsidiary question: is the use of your method a systematic policy in your department or it applied only to a few selected patients?

Dr Kuratani: That's a very difficult question. This operation is not so risk invasive, I think. So this operation, I avoid thoracotomy and the postoperative paraplegia rate is very low. This point is very good for this operation. The hybrid operation with this TEVAR operation, I think in the future, if the branched stent-graft is approved, maybe we can use this stent-graft. But now we cannot use this stent-graft, so as such avoids postoperative paraplegia, maybe this operation is an advantage for such a patient.

Dr Bachet: Yes. But I'm somewhat surprised that you focus only on paraplegia. There are other complications in this kind of surgery, like death, for instance. Having done a few cases of vascular surgery in my life, I know, as everybody here, that from time to time those Dacron prostheses get occluded. For instance, when you put the two renal arteries in the same mustache on an iliac deviation as I've seen on one of your slides, in how many patients will this occlude in the future? You don't know. And we know that surgery is not always perfect. I mean, the grafts might be too long and kink, they can be too short and be stretched, et cetera. So don't you think that you may be trading a risk for another higher risk?

Dr Kuratani: You say that maybe we use a long bypass, so there is some trouble in the future. But we have a long-term result in the 10 years. We have two cases with a left occlusion. One case in the renal artery occlusion, and one case the supramesenteric artery bypass occlusion, and there is no kinking. This is a technical problem. We changed the operation and change it, change it, change it. And before we used a long bypass on each visceral bypasses. And now we use this bypass system. After changing to this bypass system, we have no occluded and also no kinking and no problem about the graft problem.

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CURRENT TOPICS REVIEW ARTICLE

Current strategy of endovascular aortic repair for thoracic aortic aneurysms

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Abstract Thoracic aortic aneurysms are extremely burdensome to treat owing to their surgical complexity. In particular, major postoperative complications lower significantly patients' quality of life. Surgical treatment has recently shifted to thoracic endovascular aortic repair (TEVAR) to respect the patients' needs and improve postoperative quality of life. This procedure is radical and innovated for thoracic aortic pathology, but the devices and the delivery systems are immature because only a little over a decade and a half has passed since starting to use them. Ready-made stent-grafts were originally indicated only for degenerated aortic aneurysms, but aortic dissection and traumatic aortic transection will become the next targets for TEVAR. This review addresses the history and changes in TEVAR as well as the current TEVAR strategy. Finally, we describe a new trial of TEVAR for aortic dissections, traumatic aortic transections, and aortic arch aneurysms.

Key words Endovascular aortic repair · Thoracic aortic aneurysm · Aortic dissection · Stent-graft · Hybrid procedure

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Introduction

Thoracic endovascular aortic repair (TEVAR) for aortic pathology is a young procedure as it has only been a little over a decade and a half from the first clinical procedure.[1–4] The procedure is radical and innovative, but technology has not kept up with medical advancements. It is expected that this procedure will have a successful future.

However, we should not forget that the good results of TEVAR rest on the achievement of graft replacements for aortic aneurysms, and the operative methods should be chosen only after evaluating the risks and benefits.[5] Hence, we should not hesitate to perform conventional surgery when a case is beyond the reach of TEVAR.

To clarify the issues surrounding TEVAR, we first explain the functions of TEVAR and then outline the treatment strategy for each pathology seen in the thoracic descending aorta and the aortic arch. Finally, the future possibilities of TEVAR are described.

TEVAR devices

In Japan, we started performing endovascular aortic repair for type B dissections with homemade devices in 1993.[6] These stent-grafts were made of thin-walled polyester grafts and stainless Z stents.

In Europe, 12 kinds of ready-made stent-grafts for thoracic aortic aneurysms were approved; and in the United States, Gore thoracic aortic graft (Gore TAG; Gore, Newark, DE, USA) , TX2 (Cook, Spencer, IN, USA), and Talent graft (Medtronic, Grand Rapids, MI, USA) were approved by the U.S. Food and Drug