Aus der
Herzchirurgischen Klinik und Poliklinik
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Aktuelle Aspekte der Chirurgie der proximalen thorakalen Aorta

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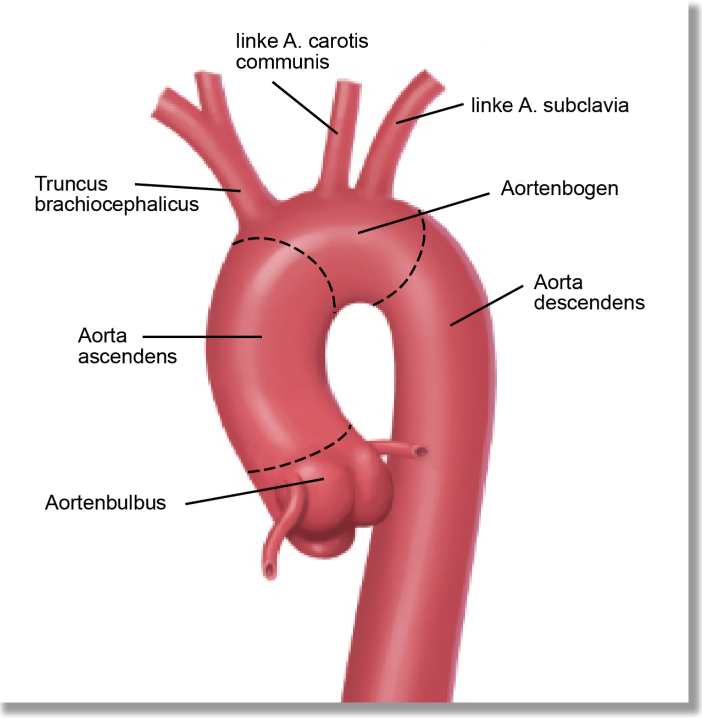
1. Einleitende Zusammenfassung

1.1 Hintergrund

Die Empfehlungen der Fachgesellschaften zur operativen Sanierung von Aortenpathologien basieren auf einer empirischen Datenlage. Die Wahrscheinlichkeit für das Auftreten einer fatalen oder letalen Komplikation im Langzeitverlauf, wie Ruptur oder Dissektion, muss dabei zur Indikationsstellung gegen das operative oder interventionelle Risiko abgewogen und der Zeitpunkt und Umfang der Sanierung beiden Kriterien kritisch angepasst werden [1-3]. Zudem sind das Risiko und die operativen Ergebnisse möglicher Folgeeingriffe in die Überlegungen einzuschließen.

Während endovaskuläre Therapieverfahren, die dem Patienten einen schonenderen Eingriff ermöglichen können, sich im Bereich der deszendierenden und abdominellen Aorta weitreichend etabliert haben, ist der klassische offene Operationsansatz im Bereich der proximalen thorakalen Aorta v.a. aufgrund anatomischer Gegebenheiten weiterhin Goldstandard. Dieser Bereich (Grafik 1) umfasst die funktionelle Einheit aus Aortenklappe und Aortenbulbus mit den drei Sinus valsalvae (Synonym: Aortenwurzel), den sinutubulären Übergang, die tubuläre aszendierende Aorta und letztendlich, aus embryologischen Gesichtspunkten, auch mindestens noch den aufsteigenden Teil des Aortenbogens [4-6].



Grafik 1: Anatomie der thorakalen Aorta.
(modifiziert mit freundlicher Genehmigung von John A. Elefteriades und Bulat A. Ziganshin)

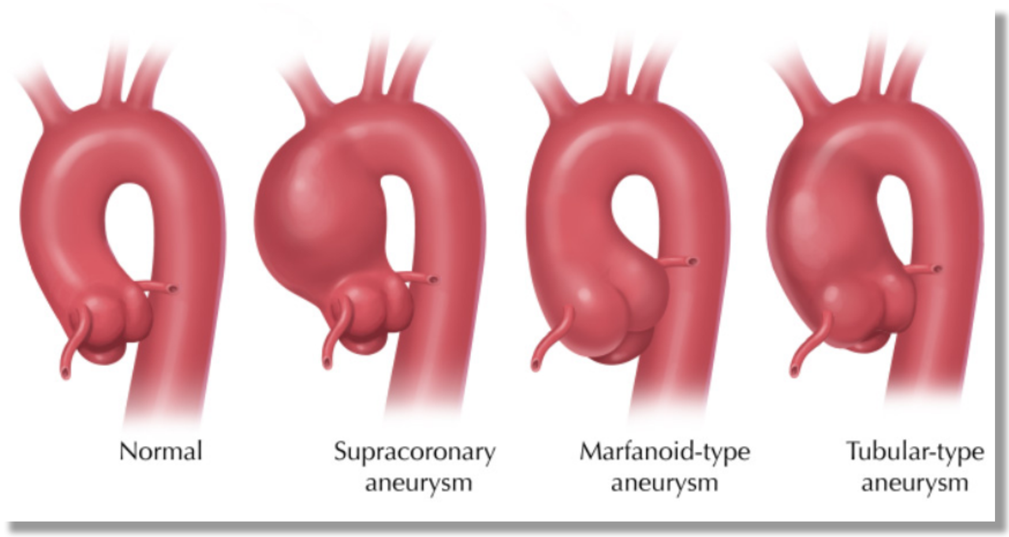
Die kontinuierlichen Entwicklungen im chirurgischen und kardiotechnischen Bereich sowie die Etablierung von Kompetenzkliniken und -zentren für Aortenerkrankungen haben die operative Sanierung der proximalen Aorta im letzten Jahrzehnt vielerorts zu Routineeingriffen gemacht und immer komplexere Therapiestrategien ermöglicht. Signifikant verbesserte Therapieergebnisse führten zu einer Verlagerung der Indikation zur Sanierung in Richtung deutlich kleinerer Gefäßdurchmesser als die Empfehlungen der Fachgesellschaften vorgeben. Das Ausmaß der gerechtfertigten Progression oder aber Restriktion des operativen Vorgehens in diesem Bereich bleibt allerdings weiterhin kritischer Diskussionspunkt, zumal wissenschaftlich fundierte Daten fehlen und die zugrundeliegende Pathologie einbezogen werden muss.

1.2 Pathologie und chirurgische Einteilung

Degenerative Aneurysmen sind die häufigste Pathologie der thorakalen Aorta und treten mit einer jährlichen Inzidenz von 5-15 Fällen pro 100.000 Einwohner auf, Tendenz steigend [7-10]. Die Ursachen für deren Entstehung und zeitlichen Progress sind heterogen [11, 12]. Das klassische degenerative Aortenaneurysma entsteht in der Regel auf dem Boden einer Arteriosklerose und unterliegt den dafür typischen prädisponierenden Faktoren. Darüber hinaus können sich hereditäre Erkrankungen des Bindegewebes ebenfalls durch eine Dilatation der Aorta manifestieren. Dazu zählen neben den komplexen genetischen Erkrankungen wie dem Marfan-Syndrom, welches auf Mutation des *Fibrillin-1* Genes beruht, auch die familiär non-syndromale, also nicht auf eine bekannte Mutation zurückzuführende Genese mit familiärer Häufung [13, 14].

Physikalisch gesehen verliert die Aorta durch eine erhöhte Wandspannung und reduzierte Dehnbarkeit ihre Elastizität und kann auf die Gefäßwand einwirkenden Druck nicht mehr adäquat absorbieren [15]. Aus chirurgischer Sicht werden diese Aneurysmata nach ihrer anatomischen Lokalisation eingeteilt (entsprechend Grafik 1), können allerdings auch wie u.a. im angloamerikanischen Raum nach Ihrem Phänotyp in suprakoronare (Synonym: suprakommissurale) – als z. Bsp.

poststenotische Dilatation (siehe auch 2.1) –, marfanoide und tubuläre Aneurysmen unterteilt werden (Grafik 2).



Grafik 2: Darstellung der unterschiedlichen Phänotypen des Aortenaneurysma im proximalen Anteil. (Quelle: Tips in Aortic Surgery (Science International Corp., Stamford (CT), 2018 [in press]; mit freundlicher Genehmigung von John A. Elefteriades und Bulat A. Ziganshin)

Nach den entsprechenden klinischen Symptomen des Patienten werden zudem noch symptomatische von nicht-symptomatische Aneurysmata unterschieden.
Von den chronisch-degenerativen Aortenerkrankungen sind die akuten, meist lebensbedrohlichen Pathologien abzugrenzen. Der Begriff *akutes Aortensyndrom* beschreibt drei Patholgien – Aortendissektion, intramurales Hämatom (IMH) und penetrierendes Aortenulkus (PAU) –, die sich zwar mit gleicher Symptomatik präsentieren, allerdings weder pathologisch noch klinisch uniform sind [16]. Die häufigste Form ist die *Aortendissektion* mit einer Inzidenz von 0,5-4 Fälle/100.000 Einwohner/Jahr [17]. Pathophysiologisch kommt es zu einer longitudinalen Aufspaltung der zumeist vorgeschädigten Tunica media. Aortendissektionen sind aufgrund von Sekundärkomplikationen wie Ruptur, Tamponade, kardialer Dekompensation (z. Bsp. aufgrund einer akut-auftretenden Aortenklappeninsuffizienz) und Malperfusion von Endorganen prognostisch ungünstig und unterliegen unbehandelt – wenn im aszendierenden Anteil lokalisiert – einer hohen Letalität. Klassifiziert wird eine Dissektion entweder nach

anatomischen Gesichtspunkten in der *DeBakey* Klassifikation (Typ I, II und III) [18], oder nach prognostischen und therapeutischen Konsequenzen in der *Stanford* Klassifikation (Typ A und B) [19]. Bei der klinisch gebräuchlicheren *Stanford* Klassifikation beziehen die pathologischen Veränderungen beim *Typ A* die Aorta ascendens mit ein, während beim *Typ B* die Dissektion erst distal der linksseitigen Arteria subclavia, sprich in der deszendierenden Aorta beginnt. Pathologien, deren proximale Ausdehnung im Bereich des Aortenbogens beginnt, sind sehr selten und wurden bisher sehr individuell unterschiedlich beurteilt. Mittlerweile werden diese als *Non-A non-B* Dissektionen zusammenfasst, allerdings ist deren Stellenwert noch ohne wissenschaftlich-fundierte Evidenz [20-22].
Das penetrierende Aortenulkus ist weitaus seltener und entsteht durch Ulzeration der elastischen Gefäßlamina im Rahmen einer fokalen Arteriosklerose. Die Pathogenese des intramuralen Hämatoms als dritte Form des akuten Aortensyndroms, sowie die Alleinstellung als separates Krankheitsbild werden weiterhin durchaus kontrovers diskutiert, allerdings heute in vielen Schwerepunktzentren wie eine Dissektion behandelt. Beide Pathologien sind nicht Gegenstand der durchgeführten Forschungsprojekte.

1.3 Risikostratifizierung und Empfehlungen der Fachgesellschaften

Degenerative Aortenaneurysmen

Das operative Risiko eines elektiven Aorteneingriffs setzt sich aus dem rein chirurgisch-technischen Aspekten und der Notwendigkeit der extrakorporalen Zirkulation mit kardioplegen Herzstillstand zusammen. Dem gegenüber ist das Risiko für eine Sekundärkomplikation – v.a. Ruptur oder Dissektion – abzuwägen. Die Risikostratifizierung basiert dabei in der Regel lediglich auf dem maximalen absoluten Diameter der Aorta und möglichen weiteren Kovariaten: die Größenzunahme innerhalb eines definierten Zeitraums, die zugrundeliegende Ätiologie, die Symptomatik des Patienten und bestehende Komorbiditäten [15]. Das zentrale Bewertungskriterium *maximaler Diameter* unterliegt allerdings Faktoren wie Größe und Alter des Pateinten und ist häufig durch die komplexe Geometrie von Aneurysmen nicht immer eindeutig zu bestimmen. Die Festsetzung der

Grenzwerte basiert dabei auf Verlaufsstudien der 90er Jahre, die einen mathematischen *„hinge point“* für das Auftreten von Sekundärkomplikationen bei 60 mm Maximaldurchmesser definiert haben [23]. Diese Ergebnisse wurden durch weitere Studien bestätigt [24-26]. Aktuelle Daten der Arbeitsgruppe an der *Yale Universität* konnten in einer deutlich größeren Population noch einen zweiten, deutlich früheren *„hinge point“* zwischen 52,5 und 55 mm berechnen [27].
Die amerikanischen (Evidenzklasse und -level in rot aufgeführt) und europäischen Fachgesellschaften (Evidenzklasse und -level in blau aufgeführt) empfehlen einen elektiven Ersatz an der aufsteigenden Aorta ab einem Durchmesser von 55 mm (Evidenz IC bzw. IIaC) oder einer Größenzunahme von 5 mm/Jahr (Evidenz IC) durchzuführen [1, 2]. Das Marfan-Syndrom (Indikation bei 40-50 mm, Evidenz IC bzw. I/IIaC), das Loeys-Dietz-Syndrom (Indikation bei 44-46 mm, Evidenz IIaC), eine zusätzlich indizierte Intervention an der Aortenklappe (Indikation ab 45 mm, Evidenz IC / IC) und andere Kofaktoren wie eine Aortenisthmusstenose und bekannte Aortendissektionen in der Familienanamnese senken die diametrischen Grenzwerte der Interventionsempfehlungen. Für die bikuspide Klappenmorphologie wurde ebenfalls ein niedriger Grenzwert zur operativen Sanierung aufgeführt, dieser wurde allerdings in den amerikanischen Richtlinien 2016 aufgrund unklarer Datenlage zurück auf 55 mm revidiert [28]. Bei symptomatische Patienten ist die Indikation unabhängig vom Diameter zu stellen (Evidenz IC). Trotz zahlreicher wissenschaftlicher Arbeiten beruhen die Empfehlungen jedoch auf einer empirischen Datenlage.

Akute Aortendissektion

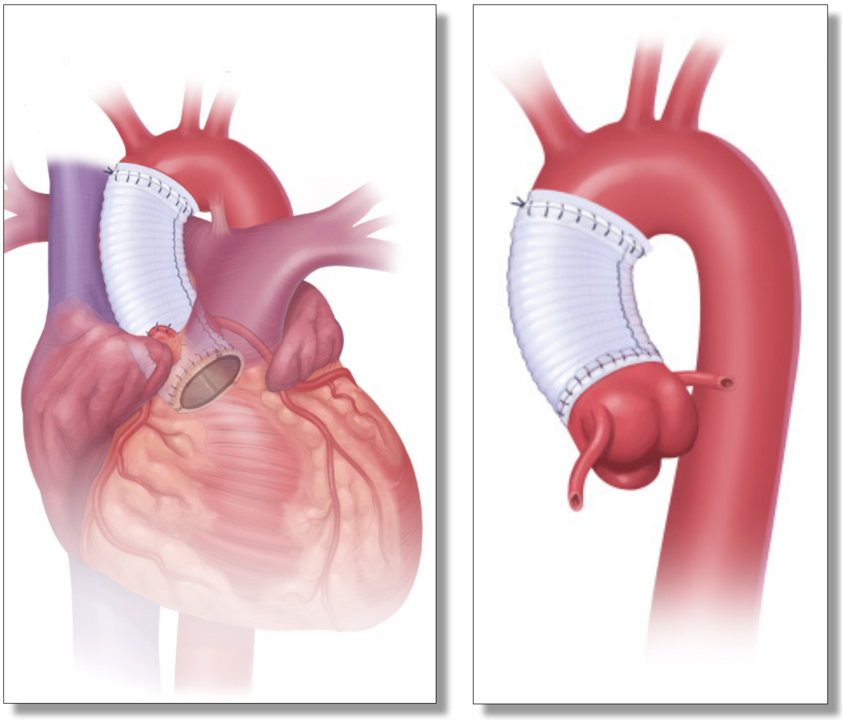
Aufgrund der Inzidenz an v.a. kardialen und zerebralen Sekundärkomplikationen mit hoher Letalität bedürfen die Aortendissektion Stanford Typ A – also der proximalen thorakalen Aorta – einer sofortigen Sanierung (Evidenz IB / IB), während eine Behandlung der Stanford Typ B Dissektion lediglich bei kompliziertem Verlauf indiziert ist (Evidenz IC / IC)[1, 2, 29]. Hierzu zählen Malperfusionen, Progression der Dissektion, Größenzunahme, therapierefraktärer arterieller Hypertonus und Persistieren der Symptomatik.

1.4 Forschungsschwerpunkte

Für den operativen Therapieansatz von Aneurysmen sind also nach aktueller Evidenz der maximale Diameter des entsprechenden Teilabschnittes der Aorta, welcher das Risiko für mögliche Komplikationen im Verlauf – Aortendissektion, Ruptur oder plötzlicher Tod – definiert, und das operative Risiko maßgebend, bei Aortendissektionen die Lokalisation. Die zusammengefassten Forschungsarbeiten reflektieren die aktuellen Ergebnisse der operativen Sanierung der proximalen thorakalen Aorta in Bezug auf die Pathologie, eruieren den longitudinalen Progress der aortalen Grunderkrankung anhand unterschiedlicher operativer Therapieansätze und erörtern mögliche Langzeitfolgen und Implikationen auf die Indikationsstellung. Die Schwerpunkte liegen dabei besonders auf den suprakommissuralen Operationsstrategien sowie Aorteneingriffen im hohen Patientenalter aufgrund des demographischen Wandels im 21. Jahrhundert.

2. Eingriffe im Bereich des aufsteigenden Anteils der thorakalen Aorta

Grundsätzlich unterscheidet man im Bereich des Aortenbulbus den Ersatz der Aortenwurzel von einer suprakommissuralen (Synonym: suprakoronaren) Operationsstrategie. Der Aortenwurzelersatz kann dabei entweder als klappenerhaltende Prozedur, sprich mit der Rekonstruktion der Aortenklappe (z. Bsp. in der Technik nach David oder Yacoub [30-32]) erfolgen oder mit dem Ersatz der Aortenklappe durch Verwendung eines eine Klappenprothese tragenden Conduits [33, 34] einhergehen. Der Ersatz der Aortenwurzel (Grafik 3, links) ist v.a. durch die Notwendigkeit der Reinseration der Koronarostien in die neue Prothese technisch aufwendig und folglich risikobehaftet [34-37]. Im Vergleich dazu stellt der suprakommissurale Operationsansatz mit Resektion des sinutubulären Übergangs oberhalb der Taschenkommissuren der Aortenklappe die technisch einfachste Variante des Ersatzes der Aorta ascendens dar, belässt aber Teile des nativen Aortengewebes proximal des Ersatzes in situ (Grafik 3, rechts).



Grafik 3: Schematische Darstellung eines Aortenwurzelersatz modifiziert nach Bentall-De Bono mit einer mechanischen Conduit-Prothese (links) und eines suprakommissuralen Resektionsansatzes (rechts).

(Quelle: Tips in Aortic Surgery (Science International Corp., Stamford (CT), 2018 [in press]; mit freundlicher Genehmigung von John A. Elefteriades und Bulat A. Ziganshin)

2.1 Vorarbeiten zum Aortenaneurysma

Hintergrund

Erkrankungen der Aortenklappe und der Aorta ascendens sind aufgrund verschiedener Kausalitäten häufig miteinander assoziiert. Rund 1-2% aller Patienten benötigen im Langzeitverlauf nach einem isolierten Aortenklappenersatz einen sekundären Eingriff an der Aorta [38]. Folglich spielen neben der reinen hämodynamischen Komponente, verursacht durch das pathologische Flussmuster aufgrund einer Klappenstenose (poststenotische Aortendilatation), auch intrinsische Faktoren eine Rolle [11]. Abgesehen davon kann ein Aortenaneurysma, sofern es den sinutubulären Übergang mit einbezieht, auch über eine Dilatation des Klappengerüstes mit konsekutiver Reduktion der Adaptationsfläche der Klappentaschen zu einer rein funktionellen Insuffizienz der Aortenklappe führen. Um zu charakterisieren, welche Patienten nachhaltig von einem ein-zeitigen Vorgehen in Bezug auf die Aortenklappe und Aorta überhaupt profitieren würden, wurde vorab retrospektiv ein Risikoprofil für aortale Sekundäreingriffe nach isoliertem Aortenklappenersatz erarbeitet und mit den aktuellen Empfehlungen der Fachgesellschaften verglichen.

Methodik

Die Datenbank des *Aortic Institutes* der *Yale Universität* beinhaltet Daten von über 3.300 Patienten, beginnend seit 1996. Diese Datenbank wurde retrospektiv nach Patienten mit sekundärem Aorteneingriff nach isoliertem Aortenklappenersatz als Primäroperation analysiert. Eingriffe aufgrund eines akuten Aortensyndroms wurden ausgeschlossen. Die demographischen und operativen Daten wurden zum Herausarbeiten der Risikofaktoren eines Sekundäreingriffes mit den Daten von 159 konsekutiven isolierten Aortenklappeneingriffen während desselben Zeitraumes verglichen. Aufgrund des limitierten Zeitrahmens der Datenbank konnten eine reine Longitudinalstudie der isolierten Aortenklappeneingriffe nicht sinnvoll erfolgen.

Ergebnisse

Einundfünfzig Patienten konnten im Zeitraum von 1996 bis 2014 mit den Einschlusskriterien der Studiengruppe identifiziert werden (Tabelle 1). Das mittlere Intervall zwischen primärem Aortenklappen- und sekundärem Aorteneingriff war 12,7 ± 6,3 Jahre und der mittlere Aortendurchmesser zum Zeitpunkt der Sekundäroperation lag bei 55,4 ± 7,5 mm.

	Reoperation an der Aorta (Studiengruppe)		**Keine** Reoperation an der Aorta (Kontrollgruppe)		*p* Wert
n =	**52**		**159**		
Alter [Jahre]	48 ± 16	[10-78]	70 ± 13	[22-90]	**< .001**
Männlich	34	65%	93	59%	.418
Pathologie der Aortenklappe					
Stenose	36	69%	139	87%	**.005**
Insuffizienz	16	31%	20	13%	**.005**
Morphologie der Aortenklappe					
bikuspid	42	81%	55	35%	**< .001**
Co-Morbiditäten					
Koronare Herzerkrankung	8	15%	18	11%	.469
COPD	11	21%	17	11%	.062
Nikotinabusus (inkl. ex)	10	19%	61	38%	**.011**
Diabetes mellitus	6	12%	35	22%	.101
Dyslipidämie	26	50%	95	60%	.259
Arterieller Hypertonus	38	73%	118	74%	.858
Pulmonaler Hypertonus	7	13%	24	15%	1.000
LVEF [%]	58 ± 11	[20-75]	55 ± 13	[20-75]	.310
Prothese					
Durchmesser [mm]	24 ± 3	[17-29]	21 ± 2	[17-29]	**< .001**

Tabelle 1: Prädiktive Faktoren für das Risiko eines sekundären Aorteneingriffes nach isoliertem Aortenklappenersatz. Die Daten zeigen den Mittelwert ± Standardabweichung und das [Intervall], oder Anzahl und Prozent. *COPD: chronisch obstruktive Lungenerkrankung; LVEF: linksventrikuläre Ejektionsfraktion.*

Zusammenfassend waren Patienten, die eine spätere interventionspflichtige Erweiterung der Aorta aufwiesen, signifikant jünger (mittleres Alter der Studiengruppe war 48 ± 16 Jahre mit einem 95%-Konfidenzintervall von 42 bis 52 Jahren, im Vergleich zu 70 ± 13 Jahren in der Kontrollgruppe; $p < 0.001$), die Prävalenz einer bikuspid-angelegten Aortenklappe war deutlich erhöht (82% vs. 35%; $p < 0.001$), die führende Pathologie war überproportional eine Klappeninsuffizienz (31% vs. 13%; $p = 0.005$) und es wurden initial Klappenprothesen mit einem größerem Diameter implantiert (24 ± 3 vs. 21 ± 2 mm; $p < 0.001$). Die Aortendurchmesser zum Zeitpunkt der Primäroperation (erfolgt zwischen 1979 und 2012) waren in der Studiengruppe leider aufgrund der lückenhaften Datenlage nur in 24% verfügbar und ließen eine fundierte wissenschaftliche Aussage nicht zu.

Diskussion

In dieser Studie standen sowohl die Klappenmorphologie als auch die -pathologie in kausalem Zusammenhang mit der Notwendigkeit eines aortalen Sekundäreingriffes nach isoliertem Aortenklappenersatz. Eine bikuspide Klappenmorphologie als häufigster angeborener Herzfehler stellt ein heterogenes Krankheitsbild mit komplexer genetischer Vererbung dar. Neben pathologischen Flussmustern, die unter anderem in Abhängigkeit zum Fusionstyp der Klappentaschen unterschiedlich stark ausgeprägt sind [39], wurden auch molekularbiologische Veränderungen in der Tunica media der Aortenwand beschrieben [40-42]. Folglich empfahlen die Fachgesellschaften den Ersatz der Aorta bereits unterhalb der allgemein gültigen 55 mm Durchmesser durchzuführen [1].
Biomechanische und histopathologische Studien ließen jedoch Zweifel aufkommen, ob diese Assoziation zu Aortenerkrankungen entsprechend verallgemeinert bzw. für stenotische Pathologien bikuspider Klappen gänzlich verneint werden kann [43-48]. In dieser Studie konnte – passend zu Beschreibungen in der Literatur – eine entsprechende Kombination aus bikuspider Morphologie und Insuffizienz als Pathologie – dem sogenannten *„root phenotype"* – als prädisponierend für eine Aortenerkrankung nachgewiesen werden (25,0% vs. 5,6%; $p < 0.001$). Die

Fachgesellschaften hatten aufgrund der derzeit noch fehlenden Evidenz in der Literatur 2016 die Empfehlungen bezüglich der bikuspiden Klappe auf einen Interventionsgrenzwert von 55 mm revidiert, interessanterweise aber für erfahrene Aortenzentren eine niedrigere Schwelle von 50 mm definiert (Evidenz IIaB)[28].
Das Patientenalter kleiner 60 Jahre ist ein weiterer wichtiger Indikator für spätere Sekundäreingriffe und ist zum Teil aber auf die Prävalenz bikuspider Klappen in der Studiengruppe zurückzuführen. Die bikuspide Morphologie führt bekanntermaßen deutlich früher zu interventionsbedürftigen Klappenpathologien als trikuspid-angelegte Aortenklappen. Darüber hinaus haben longitudinale Verlaufsstudien gezeigt, dass die Diameterprogression einer Aorta im aufsteigenden Teil ca. 1-2 mm pro Jahr beträgt [49]. Folglich ist das Risiko für Sekundäreingriffe in der Aorta bei Patienten jüngeren Alters allein durch zeitliche Faktoren deutlich erhöht. Trotz dieser Erkenntnisse wird das Patientenalter in den Richtlinien der Fachgesellschaften nur bedingt aufgeführt.
Wie bereits oben erwähnt, war die Datenlage bezüglich der Aortendiameter zum Zeitpunkt des initialen isolierten Aorteneingriffes aufgrund des großen Zeitintervalls lückenhaft und somit konnte keine Aussage bezüglich des diametrischen Grenzwertes zwischen konservativer und operativer Therapie getroffen werden.
Interessanterweise war in der Studiengruppe keine syndromale Bindegewebserkrankung wie das Marfan-Syndrom nachweisbar. Dies ist auf die konsequente Abteilungspolitik zurückzuführen, die bei diesen Patienten eine gleichzeitige progressive Intervention an der Aorta vorsieht.

2.2 Aortenklappenvitium mit Aneurysma der Aorta ascendens: Stellenwert des suprakommissuralen Aorta ascendens-Ersatz bei nicht-syndromalen Genesen (Originalarbeit 5.1)

Hintergrund

Die Fachgesellschaften empfehlen bei der Koinzidenz einer Aortenklappenpathologie – wie oben aufgeführt – die Aorta progressiv ab 45 mm Durchmesser zu ersetzen [1, 2, 15]. Die beiden Operationsstrategien – progressiver Ersatz bei um die 45 mm oder restriktives Belassen der nativen Aorta – werden jedoch häufig kritisch v.a. in Hinblick auf das operative Risiko solcher Kombinationseingriffe diskutiert. Sofern die Resektion der Aorta suprakommissural erfolgen kann, sollte das additive Risiko durch den Aortenersatz theoretisch vernachlässigbar sein. Dennoch beschreiben Studien aus den 90er Jahren eine Mortalität von 6-7%, verbunden mit einer signifikanten Anzahl an postoperativen Morbiditäten [50].

Seit den 90er Jahren haben sich komplexe Aorteneingriffe immer mehr zur klinischen Routine mit immer besseren Ergebnissen entwickelt. Mit dieser Forschungsarbeit sollte das Risiko von kombinierten Eingriffen an der Aortenklappe und Aorta ascendens mit Aussparung der Aortenwurzel in der heutigen Zeit analysiert werden.

Methodik

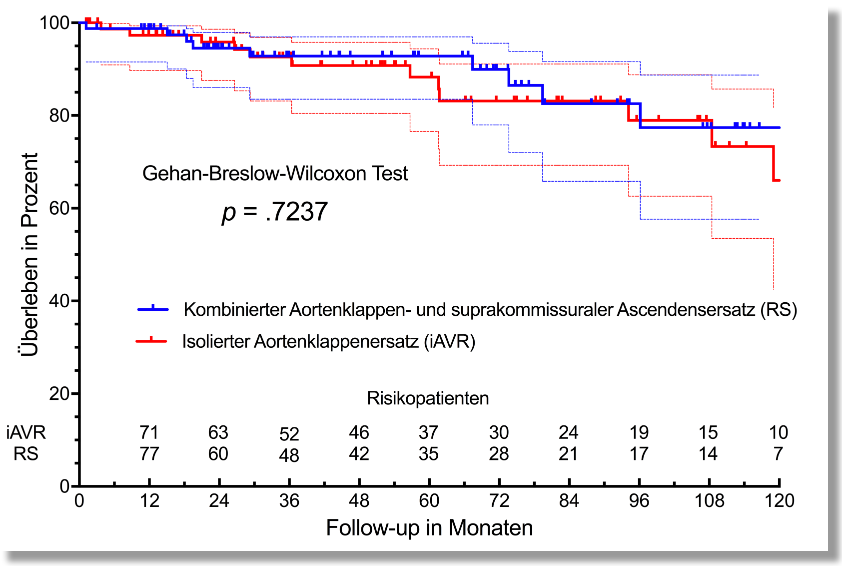
Es erfolgte die retrospektive Auswertung der Daten zwischen 2004 und 2014 am *Aortic Institute* der *Yale Universität.* Alle konsekutiven Kombinationseingriffe aufgrund von Aortenklappenpathologien und aneurysmatischen Aufweitungen der aufsteigenden Aorta wurden analysiert und nach *Propensity Score Matching* mit einer Kontrollgruppe bestehend aus konsekutiven isolierten Aortenklappenersätzen im selben Zeitraum verglichen. Akutereignisse wie Dissektionen und syndromale Bindegewebserkrankungen wie das Marfan-Syndrom oder ähnliche wurden kategorisch ausgeschlossen. Endpunkte waren die operativen Daten, die frühen postoperativen Ergebnisse sowie klinische Langzeitdaten.

In einer Subgruppenanalyse wurde zudem die Studiengruppe ebenfalls mittels *Propensity Score Matching* in Hinblick auf die distale Ausdehnung des Resektionsbereiches auf den Aortenbogen (geschlossene Anastomose oder offene Anastomose mit der Notwendigkeit des hypothermen Kreislaufstillstands [51]) untersucht. Es konnten insgesamt 182 konsekutive Patienten identifiziert werden. Für die Hauptanalyse konnten 81 Paare zusammengeführt werden, für die Subgruppenanalyse 71 Paare.

Ergebnisse

Hauptanalyse

Von operativer Seite her, waren die Zeit an der Herz-Lungenmaschine um 53 Minuten und die Aortenklemmzeit um 32 Minuten in der Studiengruppe (Kombinationseingriff) verlängert ($p < 0.001$). Postoperativ zeigte die Studiengruppe eine höhere Inzidenz an protrahierter invasiver Beatmung (definiert als > 48 Stunden; $p = 0.028$) sowie einen im Mittel um 0,9 Tage verlängerten Aufenthalt auf der Intensivstation ($p = 0.025$). Die Dauer des Krankenhausaufenthaltes und andere Komorbiditäten wie Nachblutungen, akutes Nierenversagen und Schlaganfälle zeigten keinen Unterschied zwischen den Gruppen. Die Mortalitätsrate lag in beiden Gruppen bei 0%. Auch die Kaplan-Meier Überlebensschätzung (Grafik 4) sowie klinische Langzeitdaten waren vergleichbar.

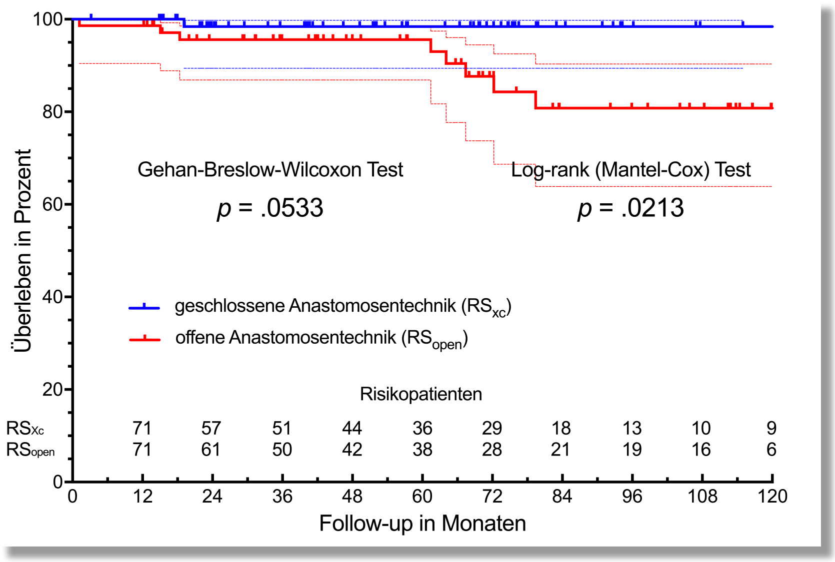


Grafik 4: Kaplan-Meier Überlebens-schätzung mit 95%-Konfidenzintervall von kombinierten Aortenklappen- und suprakommissuralen Aortenersätzen (blaue Kurve) im Vergleich zu isolierten Aorten-klappeneingriffen (rote Kurve).

Subgruppenanalyse

Es konnte kein statistisch signifikanter Unterschied zwischen der geschlossenen distalen Anastomose und der offenen im hypothermen Kreislaufstillstand (18°C Körperkerntemperatur, im Mittel 26 ± 5 Minuten Kreislaufstillstand, keine additive zerebrale Protektion) bezüglich der operativen Daten, postoperativen Morbidität und Mortalität und den Krankenhausliegezeiten gefunden werden. Die Schlaganfallrate lag bei 0% für die geschlossene und 1% für die offene Anastomosentechnik (p = 1.000). Allerdings zeigten sich doch proportionale Unterschiede mit einer höheren Inzidenz an prolongierter invasiver Beatmung, akutem Nierenversagen und der Notwendigkeit einer antibiotischen Therapie in der Gruppe mit Kreislaufstillstand. Die Überlebensfunktion (Grafik 5) zeigte ab dem 5 Jahr nach Operation auch statistisch einen signifikanten Unterschied.

Grafik 5: Kaplan-Meier Überlebensschätzung mit 95%-Konfidenzintervall im Vergleich geschlossene (blaue Kurve) gegen offene Anastomosentechnik (rote Kurve) im Bereich des aufsteigenden Aortenbogens.



Diskussion

Diese Studie zeigt, dass, im Vergleich zu älteren Daten aus der Literatur, ein zusätzlicher suprakommissuraler Ersatz der Aorta ascendens das operative Risiko eines Aortenklappenersatzes nicht erhöht. Somit kann das Operationsrisiko als Argument bei der Risikostratifizierung vernachlässigt und ein progressives Vorgehen gerechtfertigt werden. Lediglich die Erweiterung des Eingriffes in den aufsteigenden

Anteil des Aortenbogens erhöht das Risiko prozentual, aber nicht statistisch signifikant. Dies resultiert am ehesten aus der Notwendigkeit des Kreislaufstillstands in Hypothermie – hier 18°C – bei der offenen distalen Anastomosentechnik [51]. Einschränkend lässt sich bemerken, dass im untersuchten Kollektiv keine zusätzlichen zerebralen Protektionsstrategien angewandt wurden [51].

2.3 Größendynamik der verbliebenen nativen Aortenwurzel nach suprakommissuralen Aorta ascendens-Ersatz bei nicht-syndromalen Genesen (Originalarbeit 5.2)

Hintergrund

Der suprakommissurale Ersatz der aufsteigenden Aorta belässt das native Gewebe der Aortenwurzel in situ, so dass die Kenntnis der Größendynamik der Aortenwurzel nach einem solchen Operationsansatz essentiell in der Nutzen-Risiko-Abschätzung ist. Während klassische Parameter wie Reoperationsrate häufig in klinischen Studien analysiert werden, ist das Dilatationsverhalten bei nicht-syndromalen Aortenerkrankungen nur lückenhaft untersucht. Das Verhalten des belassenen Nativgewebes muss jedoch unbedingt bei der Festlegung des Grenzwertes zur Intervention und der Entscheidung des Ausmaßes der Aortenresektion mit einbezogen werden.

Methodik

In einer retrospektive Longitudinal-Studie wurden die radiologischen, echo-kardiographischen und klinischen Daten von 102 Patienten nach suprakommissuralem Aorta ascendens-Ersatz zwischen 2004 und 2011 ausgewertet. Patienten mit Akutereignissen und Bindegewebserkrankungen, die primär die Aortenwurzel betreffen, wurden ausgeschlossen. Die radiologischen Originalbilder wurden im Langzeitverlauf in Hinblick auf den maximalen Diameter der Aortenwurzel neu ausgemessen und die Diameterprogression über die Zeit mittels multivariaten Regressionsmodel ermittelt [52]. Zudem wurde der Einfluss der Kovariaten *bikuspide Klappenmorphologie* und *Aortenklappenersatz* untersucht und klinische Langzeitdaten erhoben.

Ergebnisse

Im Regressionsmodel war der Koeffizient *Zeit* positiv (0,000652) und hoch signifikant ($p < 0.0001$). Dies impliziert, dass die Aorta in der longitudinalen

Observation an Größe zunimmt. Die mittlere Progressrate betrug 0,41 mm/Jahr mit einem 95%- Konfidenzintervall von 0,35 bis 0,46 mm/Jahr (Tabelle 2).
Weder die Klappenmorphologie (p = 0.63) noch ein Aortenklappenersatz (p = 0.86) hatten einen signifikanten Einfluss auf den Diameter der Wurzel. In der klinischen Langzeitanalyse erfolgte bei keinem Patienten eine Reoperation, noch trat eine lokale Dissektion oder ein interventionspflichtiges Aneurysma im Bereich der nativen Aortenwurzel auf.

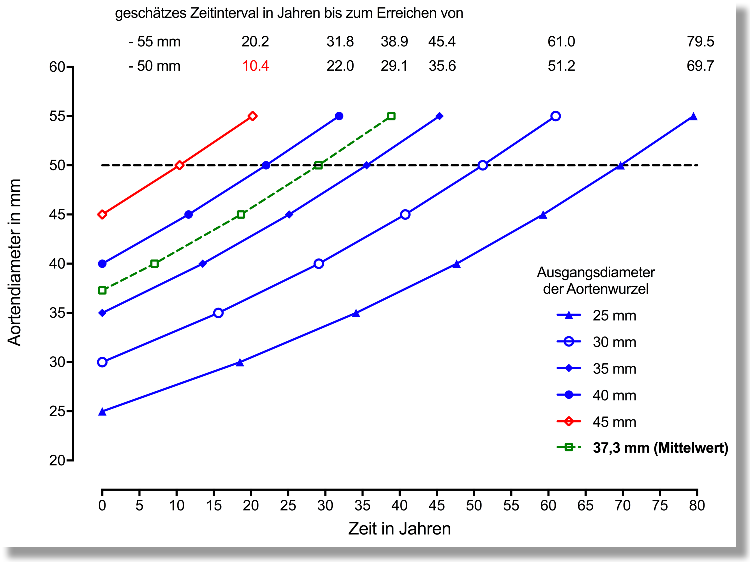
Ausgangs-	Jährliche Diameterpregression [mm/year]				
Diameter	Population	Ohne AKE	Mit AKE	BAV	TAV
n =	102	36	66	47	55
25 mm	0,27	0,27	0,26	0,28	0,26
30 mm	0,32	0,33	0,31	0,33	0,31
35 mm	0,37	0,38	0,35	0,39	0,36
40 mm	0,43	0,43	0,42	0,44	0,41
45 mm	0,48	0,49	0,48	0,50	0,47
50 mm	0,51	0,54	0,53	0,55	0,52
Mittelwert	0,41	0,42	0,40	0,42	0,40

Tabelle 2: Größenprogression pro Jahr in Abhängigkeit zum Ausgangsdiameter und verschiedener Kovariaten. *AKE=Aortenklappenersatz; BAV=bikuspide Morphologie; TAV=trikuspide Morphologie*.

Diskussion

Die Kontroverse über die Nachhaltigkeit eines rein suprakommissuralen Aortenersatz schließt v.a. den Stellenwert der belassenen nativen Aortenwurzel mit ein. Reoperationen in diesem Bereich sind technisch anspruchsvoll und immer noch mit einer signifikanten Mortalität von 5-18% vergesellschaftet [53-56]. Aufgrund dessen wird häufig die Notwendigkeit eines proaktiveren Ansatzes in Bezug auf die Aortenwurzel proklamiert [57], um neben Reoperationen auch Sekundär-komplikationen wie lokale Dissektionen zu vermeiden.

Aktuellen Daten entsprechend sollte unserer Auffassung nach eine Empfehlung hinsichtlich eines Aortenwurzelersatz zurückhaltend gestellt werden. Erstens, wie diese Forschungsarbeit gezeigt hat, ist das Risiko für die Entstehung eines sekundären Aneurysmas (Grafik 6) oder einer lokalen Dissektion in dem belassenen Nativgewebe sehr gering. Diese Ergebnisse werden von klinischen Daten der letzten Jahre gestützt [58-60].



Grafik 6: Berechnung der Diameter der Aortenwurzel über die Zeit (linear) in Bezug auf den Ausgangsdiameter bei Operation und die errechnete Progression. Die horizontale Linie repräsentiert den 50 mm Grenzwert für die Intervention in unserer Klinik.

Zweitens ist das operative Risiko eines Aortenwurzelersatz unverhältnismäßig größer [61]. Eine Metaanalyse beschreibt eine Krankenhausmortalität von 6,4% (Intervall 0-25%) bei einer Inzidenz von postoperativen Schlaganfällen von 3,7% (Intervall 0-29%) und Myokardinfarkten von 2,9% (Intervall 0-13%)[37]. Zudem gibt es eine eindeutige Korrelation zwischen der Anzahl dieser technisch aufwendigeren Prozeduren pro Jahr in einem Zentrum und den operativen Ergebnissen [62].
Dies gilt ausdrücklich nicht für Patienten mit syndromalen Bindegewebserkrankungen (wie z.Bsp. dem Marfan-Syndrom), bei denen eine aggressive Operationsstrategie in Bezug auf die Nachhaltigkeit essentiell ist.

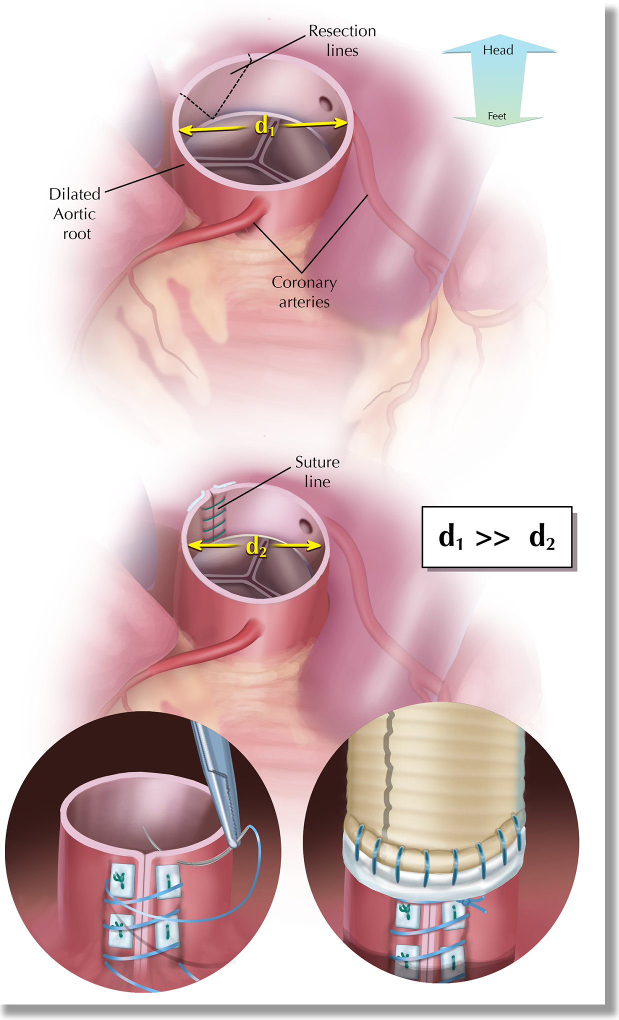
2.4 V-förmige Remodellierung des akoronaren Sinus valsalva bei Ektasie der Aortenwurzel (Originalarbeit 5.3)

Hintergrund

Aortenklappentaschen, Annulus und die Sinus valsalvae fungieren als funktionelle Einheit. Überschreiten Aneurysmen der Aorta ascendens am proximalen Anteil den sinutubulären Übergang, beeinflusst dieses die funktionelle Einheit negativ und kann eine Aortenklappeninsuffizienz bedingen, ohne dass die Klappe an sich pathologische Veränderungen aufweist. Ein Ersatz der Wurzel ist, wie oben beschrieben, mit einem deutlich erhöhten chirurgisch-technischen Risiko verbunden und steht v.a. bei älteren Patienten in keiner Relation zum Nutzen. Eine Remodellierung oder ein isolierter Ersatz eines der drei Sinus stellt eine geeignete und operationszeitsparende Alternative dar und könnte durch Reduktion der Wandspannung eine Größenprogression positiv beeinflussen [63, 64].
In einer retrospektiven Analyse wurden erste Erfahrungen mit einer an der *Yale Universität* entwickelten Remodellierungstechnik in Bezug auf die technische Machbarkeit sowie der Einfluss auf die biomechanische Wandspannung untersucht und beschrieben.

Methodik

Die Technik ist an den suprakommissuralen Ersatz der Aorta ascendens angelehnt. Nach zirkulärer Resektion des sinutubulären Übergang wird ein V-förmiges Stück der Aortenwand des akoronaren (Synonym: non-koronaren) Sinus valsalva bis hinunter zum Annulus reseziert (Grafik 7, oben). Die Resektionsränder werden zweischichtig mit einer evertierten Matratzennaht und einer fortlaufenden überwendlichen Naht wieder approximiert (Grafik 7, unten links). Im Anschluss wird der proximale Anteil der Prothese des suprakommissuralen Aortenersatz in üblicher fortlaufend anastomisiert (Grafik 7, unten rechts).



Grafik 7: Schematische Darstellung der operativen Technik der V-förmigen Remodellierung der Aortenwurzel.

Ergebnisse

Zwischen März 2013 und Mai 2016 wurde bei 12 Patienten die Aortenwurzel in beschriebener Technik remodelliert, sieben davon wiesen eine Klappeninsuffizienz auf. Es kam zu keiner technischen Komplikation oder Konversion zum Wurzelersatz. Fünf Aortenklappen wurden primär prothetisch ersetzt, bei den übrigen zwei konnte eine kompetente Klappenfunktion durch die Remodellierung erreicht werden. Der maximale Diameter der Aortenwurzel konnte von 43 mm auf 38 mm ($p < 0.006$) und der zweidimensionalen Querschnittsfläche um 19% ($p < 0.0002$) reduziert werden. Dies geht dem Laplace'schen Gesetz folgend mit einer Reduktion der biomechanischen Wandspannung um 12% einher.

Diskussion

Remodellierungstechniken im Bereich der Aortenwurzel sind eine adäquate Methode zur Reduktion des transversen Diameters der Sinus und der biomechanischen Wandspannung innerhalb der Aortenwurzel. Die V-förmige Resektion des akoronaren Sinus ist v.a. bei älteren Patienten oder Patienten mit einer geringen Ektasie der Aortenwurzel anwendbar, voll ausgeprägte Aneurysmata stellen eine absolute Kontraindikation dar.

Bei einer Koinzidenz mit einer Aortenklappenpathologie, empfiehlt sich diese Technik im Zusammenhang mit einem prothetischen Aortenklappenersatz oder einer geringgradig ausgeprägten Klappeninsuffizienz mit zentralem Jet, da es durch die Resektion und Approximation zu einem Prolaps der akoronaren Tasche der Aortenklappe kommen kann.

2.5 Suprakommissuraler Ersatz der Aorta ascendens bei der akuten Aortendissektion Stanford Typ A: Risikoreduktion und Erhalt der Integrität der nativ-belassenen Aortenwurzel (Originalarbeit 5.4)

Hintergrund

Aortendissektionen stellen eine besondere chirurgische Herausforderung dar. Dabei konkurrieren eine möglichst schnelle operative Sanierung zur Sicherung des Überlebens des Patienten (Akutergebnis) und eine möglichst vollständige Sanierung der Pathologie (Langzeitergebnis) miteinander. In Bezug auf die Aortenwurzel – wenn primär nicht disseziert und somit auch nicht zwingend zu ersetzten – stellt sich dabei die kritische Frage: Ersetzen und das Risiko für spätere Komplikationen im diesem Bereich minimieren? Oder belassen und somit die Operationszeit in der kritischen Situation des Patienten signifikant verkürzen?
Ziel des Forschungsprojektes war die retrospektive Auswertung von Patienten mit einer akuten Typ A Dissektion in Hinblick auf Ersatz oder Belassen der Aortenwurzel inklusive dessen Integrität.

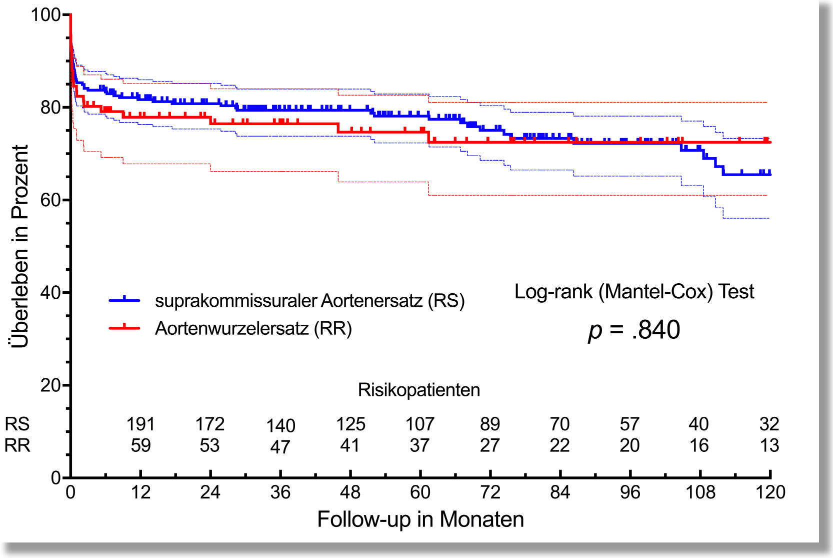
Methodik

Die Datenbanken der *Yale Universität* und *Medizinischen Universität Innsbruck* wurden retrospektiv ausgewertet und alle konsekutiven Patienten mit akuter Aortendissektion Stanford Typ A nach Operationsstrategie im Bereich der Wurzel evaluiert. Syndromale Bindegewebserkrankungen und rekonstruktive Operationsverfahren im Bereich der Wurzel mittels Gewebekleber oder Naht wurden kategorisch ausgeschlossen.
Insgesamt konnten 338 Patienten eingeschlossen werden.
Zweihundertneunundvierzig erhielten einen suprakommissuralen Ersatz der aszendierenden Aorta, 89 einen Ersatz der Aortenwurzel. Endpunkte waren die frühen postoperativen Ergebnisse und Langzeitdaten mit Fokus auf Überleben und Freiheit von *Aortalen Ereignissen* im Bereich der Aortenwurzel. Im Falle von in situ belassenem Nativgewebe wurde die Größendynamik wiederum mittels multivariaten Regressionsmodel ermittelt [52].

Ergebnisse

Postoperative Ergebnisse

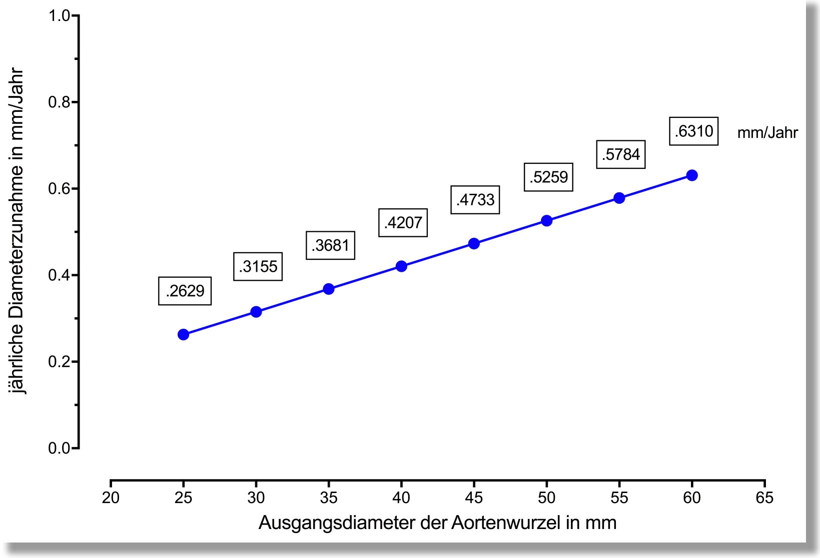
Patienten, die einen Aortenwurzelersatz erhielten, wiesen eine höhere Inzidenz an Nachblutungen (p = 0.003), Low Cardiac Output Syndrom (p = 0.002) und septiformer Kreislauflage direkt postoperativ (p = 0.037) auf. Der Krankenhausaufenthalt war zudem um 5 Tage verlängert (p = 0.048). Die operative Mortalität und das Langzeitüberleben zeigte keine Unterschiede zwischen beiden Gruppen (Grafik 8).



Grafik 8: Kaplan-Meier Überlebens-schätzung mit 95%-Konfidenzintervall im Vergleich von suprakommissuralen Aortenersatzes (blaue Kurve) und Aortenwurzelersatz (rote Kurve).

Diameterprogression

Nach stattgehabten suprakommissuralen Aorta ascendens-Ersatz dilatiert die Wurzel über die *Zeit* (Koeffizient 0,0009374; $p < 0.001$). Die jährliche Progression errechnet sich mit 0,40 ± 0,13 mm (Grafik 9). Damit unterscheidet sich die Größendynamik nach erfolgter Dissektion nicht von der einer primär aneurysmatischen Grunderkrankung (p = 0.064).



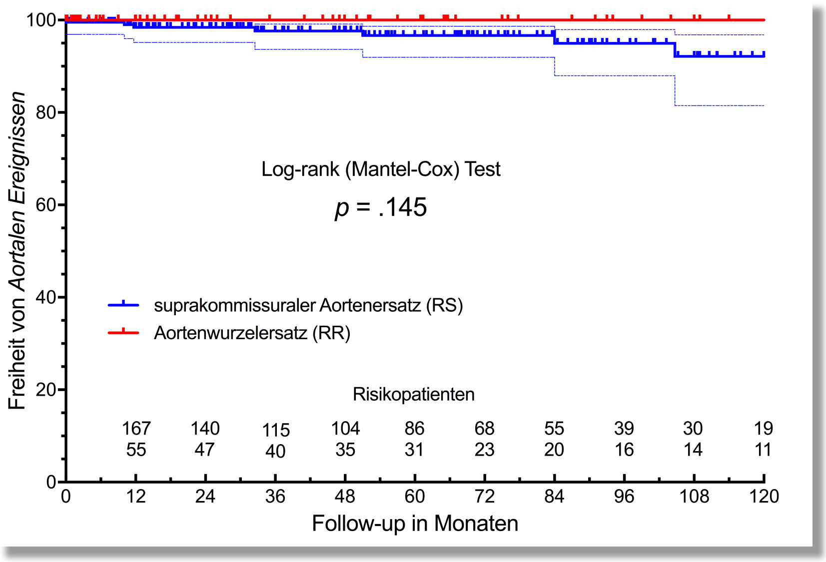
Grafik 9: Größendynamik der Aortenwurzel nach suprakommissuralem Aortenersatz pro Jahr in Abhängigkeit zum Ausgangsdiameter.

Aortale Ereignisse (AE)

Die Freiheit von *AEs* nach suprakommissuralem Ersatz, definiert als Reoperation, lokale Dissektion oder interventionspflichtiges Aneurysma in diesem Bereich, war 99% nach einem, 97% nach fünf und 92% nach 10 Jahren (Grafik 10). Von den sieben betroffenen Patienten mit einem *AE*, trat bei einem Patienten eine Anastomosenblutung im Bereich der Aortenwurzel am 1. postoperativen Tag auf, bei einem weiteren kam es im Verlauf zu einer interventionsbedürftigen Aortenklappeninsuffizienz. Bei je einem Patienten trat im Verlauf eine Protheseninfektion und eine Aortenruptur auf. Bei drei Patienten kam es zu einer Progression des Diameters der Aortenwurzel, eine lokale Dissektion im entsprechenden Bereich war bei keinem Patienten nachweisbar.

Im Vergleich dazu war die Freiheit von *AEs* in der Gruppe der Aortenwurzeloperationen 100%, allerdings ohne statistische Signifikanz im Vergleich zur suprakommissural ersetzten Gruppe (p = 0.145).

Grafik 10: Freiheit von *Aortalen Ereignissen* mit 95%-Konfidenz-intervall im Bereich der Aortenwurzel bei suprakommissuralen Aortenersatzes (blaue Kurve) im Vergleich zum Aortenwurzel-ersatz (rote Kurve).



Diskussion

Suprakommissurale Operationsverfahren zeigen auch im Falle von Aortendissektionen als Grunderkrankungen eine geringere technische Schwierigkeit, ausgedrückt in den Herz-Lungenmaschinenzeiten und den postoperativen Morbiditäten. Die operative Mortalität und das Langzeitüberleben unterscheidet sich nicht in Hinblick auf die Operationsstrategie und generiert sich am ehesten aus der Grunderkrankung.

Die Kritik, dass die nativ belassene Aortenwurzel im Langzeitverlauf ein essentielles Risiko für sekundäre Komplikationen oder Reoperationen darstellt, konnte in dieser Forschungsarbeit nicht gänzlich nachvollzogen werden. Sekundäre Komplikationen werden in der Literatur mit einer Inzidenz von 7-13% für aneurysmatische Dilatation, 3-7% für lokale Re-Dissektion, 3-5% Nahtreihen- und Pseudoaneurysmata, 3-5% für Aortenklappeninsuffizienzen und 7-16% für Reoperationen angegeben [65-67].

Im Zusammenhang mit Aortendissektionen kann hinsichtlich beider Operationsverfahren – progressiver/prophylaktischer Wurzelersatz oder restriktive Aussparung der Wurzel – argumentiert werden. Auch wenn der prophylaktische Wurzelersatz die definitivere Lösung darstellt, kann auch – wie beschrieben – ein suprakommissuraler Ersatz mit guten Langzeitergebnissen durchgeführt werden.

Bei jungen Patienten, Patienten mit Marfan-Syndrom, bikuspider Klappenmorphologie und einem Diameter der Aortenwurzel von 45 mm und größer sollte ein proaktiver Aortenwurzelersatz – wenn auch kritisch – in Betracht gezogen werden.

2.6 Schlussfolgerung

1. Patienten im Alter kleiner 60 Jahre, mit bikuspider Morphologie und gleichzeitig bestehender Klappeninsuffizienz profitieren von einem ein-zeitigen Vorgehen schon ab kleineren Aortendurchmessern (< 55 mm). Dies ist in den aktuell gültigen Empfehlungen der Fachgesellschaften nur bedingt abgebildet.
2. Ein kombinierter suprakommissuraler Ersatz der aszendierenden Aorta erhöht das operative Risiko eines isolierten Aortenklappenersatzes nicht. Lediglich die Ausweitung des Eingriffes in den aufsteigen Anteil des Aortenbogens ist mit einer proportionalen Erhöhung an postoperativen Komplikationen assoziiert.
3. Die belassene native Aortenwurzel nach suprakommissuralem Aorta ascendens-Ersatz aufgrund eines Aneurysmas dilatiert langsam und weist selten sekundäre Komplikationen auf. Ein proaktiver Ersatz der Aortenwurzel kann deshalb und aufgrund der operativen Ergebnisse nicht vorbehaltlos empfohlen werden.
4. Alternative Operationstechniken, den akoronaren Sinus betreffend, können mathematisch die biomechanische Belastung in der Aortenwurzel reduzieren, beschränken sich aber auf gewisse Ausnahmefälle.
5. Der suprakommissurale Aortenersatz ist auch im Falle einer Aortendissektion ein adäquates Operationsverfahren, ohne sekundäre Komplikationen in Bezug auf die Integrität der nativen Aortenwurzel in situ.

3. Thorakale Aortenchirurgie im Alter

Die anhaltende demographische Entwicklung in der Westlichen Welt hin zu einer immer älter werdenden Gesellschaft stellt auch die Herzchirurgie vor Herausforderungen [68]. In Deutschland kam es in den letzten 10 Jahren bereits zu einem deutlichen Anstieg des Durchschnittsalters der Patienten, die einer operativen Therapie unterzogen wurden. Sicherlich auch durch die Erschließung neuer Technologien, wie der interventionellen Klappenimplantation, stieg der Anteil an Über-70-Jährigen von 45,3 auf 53,1%, der Anteil der Über-Achtzigjährigen noch prägnanter von 8,4 auf 14,8% [69, 70]. Allerdings hat sich auch das Verhältnis zwischen chronologischen und biologischen Alter verschoben.
Altern beinhaltet umfangreiche Prozesse, die einen direkten Einfluss auf den Outcome nach herzchirurgischen Eingriffen haben können (Tabelle 3). Dies betrifft u.a. alle Komponenten der Atmung – Mechanik, Gasaustausch und pulmonale Gefäßsystem –, Veränderungen im kardiovaskulären System, Verschlechterungen der renalen Funktion, zunehmendes hormonelles Ungleichgewicht hin zum Katabolismus und neurokognitive und neurovaskuläre Veränderungen [71-75].

Organsystem	Veränderungen durch Altern
Atmung [71]	↓ Respiratorische Mechanik • ↓ Compliance der Thoraxwand • ↓ interkostale und diaphragmale Muskelkraft ↓ Gasaustausch • ↓ elastische Rückstellkräfte mit Verlust der Gesamtelastizität • Veränderungen der alveolären Struktur → ↑ alveolar-arterieller Sauerstoffgradient Pulmonales Gefäßsystem • Remodelling → ↓ vaskulären Compliance
Kardiovaskuläres System [72]	Links-ventrikuläre Hypertrophie ↓ linke-ventrikuläre Kontraktilität und Relaxation ↓ systolische und diastolische rechts-ventrikuläre Funktion ↓ β- adrenerge Ansprechbarkeit ↑ Nachlast durch ↑ Wandsteifigkeit der Arterien
Renale Funktion [73]	Glomerulosklerose Tubuläre Atrophie Fibrosierung Renal-vaskuläre Veränderungen
Hormoneller Metabolismus [74]	Ungleichgewicht Anabolismus < Katabolismus
Nervensystem [75]	Neurokognitive Dysfunktion Neurovaskuläre Veränderungen

Tabelle 3: Detaillierte Auflistung der Veränderung, die mit dem Altern verbunden sind (ohne Anspruch auf Vollständigkeit).

3.1 Elektive Eingriffe an der aszendierenden Aorta im hohen Alter: Gibt es eine Altersgrenze? (Originalarbeit 5.5)

Hintergrund

Eingriffe an der Aorta tragen trotz aller technischer Entwicklungen immer noch ein substantielles operatives Risiko. Dieses generiert sich aus den häufig notwendigen langen Zeiten an der Herz-Lungenmaschine aufgrund chirurgisch-technischer Komplexität und dem möglichen Umstand eines Kreislaufstillstandes in moderater (20-28°C) bis tiefer (14-20°C) Hypothermie [51]. Die Mortalität von Aortenchirurgie in hohem Patientenalter wird in der Literatur mit 6-21% angegeben, je nach Definition des Terminus *hohes Patientenalter* [76-81].
Ziel dieser Forschungsarbeit war das Risiko von Elektiveingriffen an der Aorta für unterschiedliche Altersgruppen zu untersuchen.

Methodik

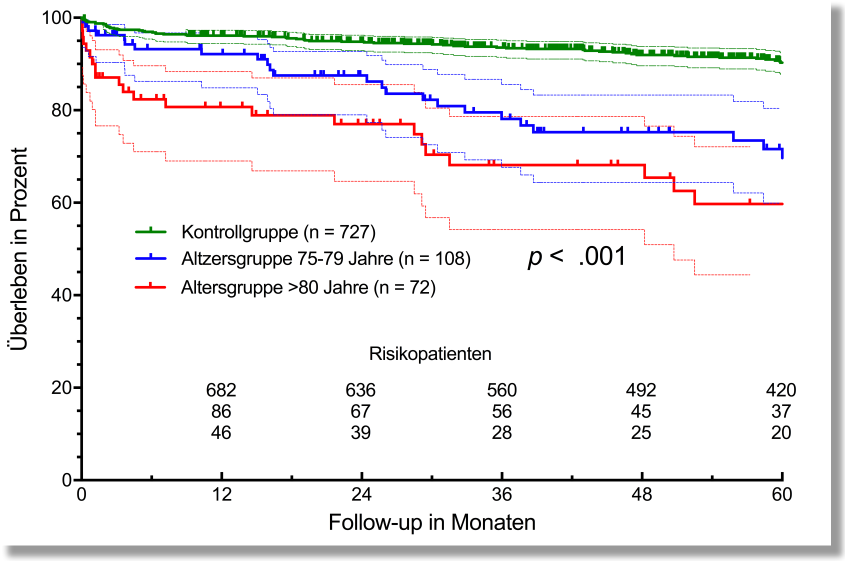
Zwischen 2000 und 2015 unterzogen sich am *Yale-New Haven Hospital* insgesamt 907 Patienten einem Elektiveingriff aufgrund eines Aneurysmas im Bereich der proximalen thorakalen Aorta. Ausschlusskriterien waren eine akute Aortendissektion oder andere Akuterkrankungen an der Aorta. Die Gesamtpopulation wurde in drei Gruppen unterteil: Patientenalter größer 80 Jahre (n=72; mittleres Alter 82,2 $\pm$ 2,1 Jahre, 47,2% männlich), Alter zwischen 75 und 79 Jahren (n=108; mittleres Alter 76,9 $\pm$ 1,5 Jahre; 60,2% männlich) und jünger als 75 Jahre (Kontrollgruppe; n=727; mittleres Alter 56,6 $\pm$ 11,7 Jahre; 74,4% männlich). Endpunkte waren das frühe postoperative Ergebnis, das Langzeitüberleben sowie prädiktive Faktoren der operativen Mortalität in einem multivariaten binär-logistischen Regression-Modell.

Ergebnisse

Ältere Patienten zeigten postoperativ unter anderem eine höhere Inzidenz an Langzeitbeatmung (definiert als invasive Beatmung > 48 Stunden; $p < 0.001$), Low Cardiac Output Syndrom ($p = 0.001$), Myokardinfarkten ($p = 0.045$), Dialysepflichtigkeit ($p < 0.001$), Infektionen ($p = 0.017$), Sepsis ($p = 0.049$) und Multiorganversagen ($p = 0.022$). Dabei war der prozentuale Anteil bei den Über-Achtzigjährigen deutlicher ausgeprägt als bei den Patienten im Alter zwischen 75 und 79. Die Krankenhausliegezeiten (p < 0.001) waren zudem mit steigendem Alter signifikant verlängert. Die operative Mortalität lag bei 11,1% für die Über-Achtzigjährigen und 3,7% für Senioren im Alter von 75-79, im Vergleich zu 1,4% in der Kontrollgruppe der jüngeren Patienten (mittleres Alter 56,6 ± 11,7 Jahre). Auch das Langzeitüberleben war signifikant verkürzt (Grafik 11).

In der univariaten Analyse bezüglich Risiko für operative Mortalität konnten neun Faktoren identifiziert werden, die sich in der multivariaten Analyse jedoch nicht als unabhängig Faktoren bestätigten. Insbesondere *Alter* als kontinuierliche Variable konnte nicht als unabhängiger Risikofaktor isoliert werden.

Grafik 11: Kaplan-Meier Überlebens-schätzung nach elektiven Aorten-eingriffen, aufgegliedert nach unterschiedlichen Altersgruppen und mit 95%-Konfidenz-intervall.



Diskussion

Patienten in höherem Lebensalter unterliegen einem deutlich größeren operativen Risiko. Die Analyse der operativen Mortalität als klassisches Surrogat für eine erfolgreiche chirurgische Therapie war signifikant höher mit steigendem Alter. Ein Grenzwert, bei dem die Mortalität signifikant ansteigt, konnte nicht identifiziert werden. In der Literatur sind solche Angaben in Bezug auf Aortenchirurgie eher selten und liegen, falls isolierbar, im Bereich um 72 Jahre [77]. Dies kann in der aktuellen Studie nicht bestätigt werden. Patienten im Alter zwischen 75 und 79 Jahren zeigen noch ein überaus akzeptables operatives Ergebnis

Ein Patientenalter größer 80 Jahre dagegen ist mit einem nicht vernachlässigbaren Risiko verbunden. Dennoch kann eine operative Intervention gerechtfertigt sein, wenn mit der Intervention entweder ein als sehr riskant eingeschätztes Aneurysma saniert oder die Lebensqualität des Patienten verbessert wird. Einige wenige Studien berichtete ein vergleichbares oder besseres Überleben durch die operative Sanierung im Vergleich zur konservativen medikamentösen Therapie [82, 83].

3.2 Therapie der akuten Aortendissektion Stanford Typ A in Über-Achtzigjährigen: Beeinflusst eine Notoperation die Prognose positiv?

(Originalarbeit 5.6)

Hintergrund

Etwas anders verhält es sich im Falle einer akuten Aortendissektion im proximalen thorakalen Bereich. Die operative Sanierung weist je nach Komplexität des operativen Ansatzes selbst in den erfahrensten Aortenzentren eine Mortalität von 8-23% auf, unabhängig vom Alter der Patienten [66, 84, 85]. Der postoperative Verlauf zeichnet sich bei jungen Patienten häufig prolongiert und zieht nicht selten wiederholte Eingriffe an den anderen Segmenten der Aorta nach sich. Andererseits, konservativ ist die Überlebenswahrscheinlichkeit aufgrund der mannigfaltigen Komplikationen, v.a. in den ersten Tagen und Wochen, deutlich geringer. Die Letalität nicht-behandelter Aortendissektion wird in den ersten 24 Stunden mit ca. 70-72% geschätzt [86, 87].

Daten über die Ergebnisse in Patienten älter als 80 sind limitiert und es stellt sich daher die Frage, ob bei den entsprechenden operativen Ergebnissen nicht ein konservativer Therapieansatz in Bezug auf ethische Aspekte und die Lebensqualität nach Intervention angemessener wäre.

Methodik

In einer retrospektiven Datenanalyse der *Yale Universität*, der *Medizinischen Universität Innsbruck* und des *Herzzentrums Leipzig* wurden die Verläufe von Patienten über dem 80. Lebensjahr ausgewertet und die Ergebnisse von konservativ und operativ behandelten Patienten verglichen. Zusammen konnten zwischen 2002 und 2015 insgesamt 90 Patienten (Durchschnittsalter 84 ± 3 Jahre) identifiziert werden, die mit der Diagnose einer akuten Aortendissektion Stanford Typ A in den entsprechenden Krankenhäusern aufgenommen wurden. Siebenundsechzig wurden operativ behandelt, 23 konservativ.

Ergebnisse

Die Gruppen unterschieden sich in den demographischen Charakteristiken bereits in Bezug auf Alter (83 ± 3 vs. 85 ± 4 Jahre; $p = 0.008$), chronisch obstruktiver Lungenerkrankung (12 vs. 32%; $p = 0.047$) und dem Vorhandensein eines Perikardergusses (36 vs. 74%; $p = 0.003$) mit der jeweils höheren Inzidenz in der konservativ behandelten Gruppe.

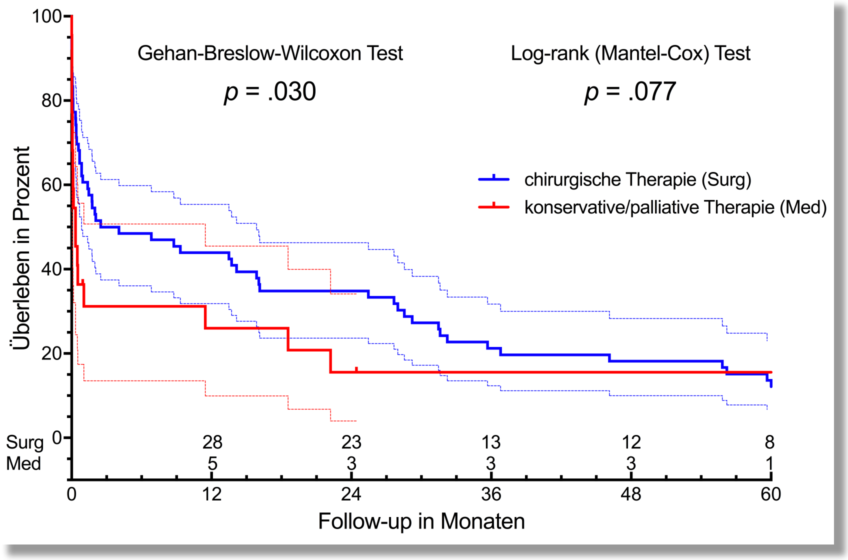
Die 30-Tage Mortalität war hoch und zeigte einen Vorteil der chirurgischen Therapie (39 vs. 65%; $p = 0.032$). Die Alters-korrigierte multivariate Analyse identifizierte koronare Herzerkrankung (OR 3,95; $p = 0.029$) und komplizierte Aortendissektion (OR 5,28; $p = 0.010$), definiert durch die präoperativen Faktoren Reanimation, neurologische Symptome und Malperfusionssyndrom, als unabhängig Prädiktoren der Krankenhaussterblichkeit. Die postoperativen Morbiditäten waren ebenfalls hoch (Tabelle 4), ein Vergleich mit der konservativen Gruppe ist jedoch aufgrund des palliativen Therapieansatzes in dieser Gruppe nicht sinnvoll.

Variable	**Inzidenz postoperativ**
Beatmung > 48 Stunden	63,2%
Tracheotomie	19,3%
Low Cardiac Output Syndrom	20,7%
Multiorganversagen	19,0%
Sepsis	8,8%
Apoplex	20,0%
Dialysepflichtigkeit	35,1%

Tabelle 4: Morbiditäten nach operativer Sanierung einer akuten Typ A Dissektion im Alter > 80 Jahre.

Das Langzeitüberlebensschätzung zeigte ebenfalls einen statistischen Überlebensvorteil in der Gruppe der operativen Therapie mit 49 ± 6% nach einem und 38 ± 7% nach drei Jahren, im Vergleich zu 25 ± 9% und 19 ± 9% in der konservativ behandelten Gruppe (Breslow Test: $p = 0.030$). Nach fünf Jahren gleicht sich allerdings die Überlebenswahrscheinlichkeit an (log-rank Test: $p = 0.077$).

Grafik 12: Kaplan-Meier Überlebens-schätzung von Patienten im Alter über 80 Jahre mit akuter Typ A Dissektion, aufgegliedert nach chirurgischer und konservativer Therapie und mit 95%-Konfidenz-intervall.



Diskussion

Die chirurgische Therapie einer akuten Typ A Dissektion bei Patienten in hohem Alter wird aufgrund von Mortalitätsraten von bis zu 83% kontrovers diskutiert wird [88], trotzdem favorisieren die meisten Europäischen Zentren doch die operative Sanierung. Anders als bei jüngeren, treten hier jedoch häufiger akute Komplikationen auf, so dass 15-33% der Patienten intraoperativ oder innerhalb der ersten 24 Stunden versterben [88]. Die medikamentöse Therapie wird überwiegend bei multimorbiden Patienten bevorzugt, ist allerdings mit einem schlechten Outcome assoziiert. Die 30-Tages-Mortalität bei konservativer Therapie beträgt unabhängig vom Patientenalter 58% [87], bei Über-Achtzigjährigen 65%, wie diese Studie zeigte. Unter Berücksichtigung der Langzeitüberlebensschätzung, ist die rein medikamentöse Behandlung als ein palliativer Therapieansatz einzuordnen. Chirurgische und konservative Therapie können also beide kein akzeptables Ergebnis der Behandlung generieren und körperliche Einschränkungen im Langzeitverlauf sind grundsätzlich wahrscheinlich. Folglich sind für die Therapieentscheidung eher soziale Faktoren vorrangig. Dazu zählen das soziale Umfeld (Familie, Partner, etc.), die Lebensumstände und die Eigenständigkeit des Patienten. Und nicht zu allerletzt der Patientenwunsch.

3.3 Schlussfolgerung

1. Bei Patienten in höheren Lebensalter (80+) sollte die Indikation zur Operation eines Aortenaneurysma weiterhin deutlich strenger gestellt werden und auf die Verbesserung der Lebensqualität abzielen. Alter per se ist aber keine Kontraindikation.

2. Die Indikationsstellung zur operative Sanierung einer akuten Aortendissektion sollte in hohem Alter immer zusammen mit den Angehörigen und streng unter Berücksichtigung der allgemeinen Lebensumstände und Eigenständigkeit der Patienten erfolgen. Die konservative Therapie ist eine palliative Behandlung.

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5. Schriftenverzeichnis der kumulativ zusammengefassten Originalarbeiten

5.1 Aortic valve disease with ascending aortic aneurysm: Impact of concomitant root-sparing (supracoronary) aortic replacement in non-syndromic patients.

Aortic valve disease with ascending aortic aneurysm: Impact of concomitant root-sparing (supracoronary) aortic replacement in nonsyndromic patients

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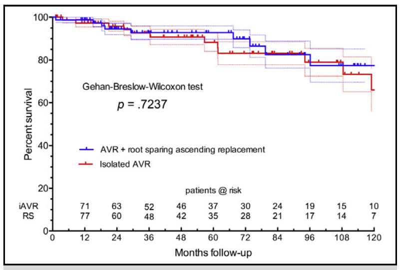
ABSTRACT

Objective: The purpose of the study was to assess the anticipated incremental risk of a concomitant aortic resection performed with an aortic valve replacement.

Methods: Patients who underwent aortic valve replacement with root-sparing ascending replacement were compared with those who underwent isolated aortic valve replacement using propensity score matching (81 pairs; mean age, 63 ± 11 years [root-sparing ascending replacement] vs 64 ± 14 years). To evaluate the impact of the technique at distal site, 71 pairs of those undergoing root-sparing ascending replacement also were matched by propensity score according to distal anastomosis performed clamped and open under deep hypothermic circulatory arrest.

Results: Operative mortality was equal between the root-sparing ascending replacement and isolated aortic valve replacement groups. No significant difference was found regarding postoperative morbidities, such as bleeding, renal failure, stroke, and length of stay, except prolonged ventilation was found after root-sparing procedures ($P = .028$). Survival estimation showed no difference between the groups. Comparing the patients undergoing root-sparing ascending replacement with clamped and opened distal anastomosis revealed a prolonged ventilation requirement (7% vs 3%; $P =$ not significant) in the open group. Operative mortality was 0% in both groups, and midterm survival was comparable.

Conclusions: The concomitant replacement of the aorta in root-sparing fashion is associated with an excellent operative outcome and adds no additional risk to aortic valve replacement in elective and non–high-risk patients. If the distal anastomosis is performed in an open fashion, while the operative mortality is still very low, morbidities are slightly higher, but midterm survival remains comparable. (J Thorac Cardiovasc Surg 2016;152:791-8)



AVR with or without ascending aortic resection showed equal survival.

Central Message

Proximal aortic replacement with the RS technique is a safe approach and can be performed with excellent operative results.

Perspective

Resecting the mildly to moderately dilated aorta at the time of AVR adds no additional morbidity and mortality risk for patients. These data are highly relevant to surgical decision making regarding the management of the aorta at the time of AVR. These data help to weigh the operative risk of aortic resection against the natural risk of aortic dissection and rupture.

See Editorial Commentary page 799.

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Weighing the risk of surgical intervention against the subsequent risks of a disease is essential in recommending a treatment strategy. In case of co-incidences of aortic valve disease and proximal thoracic aortic aneurysm, the assumed additive risk of replacing the aortic vessel

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Abbreviations and Acronyms

- AVR = aortic valve replacement
- DHCA = deep hypothermic circulatory arrest
- iAVR = isolated aortic valve replacement
- RS = root sparing

concomitantly during an aortic valve replacement (AVR) must be weighed against the potential risk of dissection and rupture when leaving the aorta alone. But, is there really a significant surgical risk from incremental aortic resection? Although a conduit replacement of the valve and the root, for example, using the Bentall technique, is known to add technical complexity,[1,2] the root-sparing (RS) approach represents a less difficult technique, avoiding detachment and reattachment of the coronary ostia because the proximal anastomosis is done above the commissures of the native valve.[3] Thus, the operative risk may not be substantial. The essential requirement for application of the RS technique is a nondiseased (not significantly dilated) root. In the 1990s, Carrel and coworkers[4] reported a mortality of 6.5% with a high incidence of postoperative morbidity for RS replacement compared with an isolated AVR (iAVR). However, since then, more complex aortic procedures have become clinically routine and are performed with excellent results in experienced centers.[5] The aim of this study was to evaluate the modern-day risk of a concomitant RS supracoronary aortic replacement compared with the isolated approach of AVR. We also examined the impact of distal extension of the resection close or into the aortic arch.

PATIENTS AND METHODS

Study Design

All consecutive patients undergoing AVR and RS (supracoronary) ascending aortic replacement by a single surgeon between 2004 and 2014 were reviewed for the present study. To compare the specific risk of a concomitant ascending aortic replacement—controlling for the general risk of a cardiac surgical procedure and the use of cardiopulmonary bypass—a contemporaneously operated control group of consecutive iAVRs was identified. Patients receiving an ascending replacement without an AVR were excluded from this study. Further exclusion criteria were total aortic arch replacement, aortic dissection, intramural hematoma, penetrating aortic ulcer, endocarditis, connective tissue disorder (Marfan, Ehlers–Danlos, Loeys–Dietz), transcatheter approaches, root replacement (Bentall, Cabrol, David, or Yacoub procedure), root remodeling, and concomitant coronary artery bypass grafting procedure.

Group propensities were adjusted by propensity score matching (details noted in "Statistical Analysis" section), and demographic characteristics, comorbidities, operative data, postoperative morbidity, and early outcome were analyzed by comparing the study group with the control group. Late complications were analyzed according to Akins and colleagues.[6] In a second step, the population receiving RS procedures was divided into 2 subgroups according to distal extension into the arch (clamped vs open distal anastomosis) requiring the use of deep hypothermic circulatory arrest (DHCA), and a comparison was performed after propensity score matching. Survival after discharge was determined from the Social Security Death Index and chart review, and the date of proven last clinical contact was used for the status "alive." The Human Investigation Committee of Yale University approved this retrospective study, and all patients signed informed consent.

Patient Population

Between 2004 and 2014, 182 consecutive patients with concomitant aortic valve and ascending aortic aneurysm disease (RS) (mean age, 61 ± 13 years; 60% were male) and 159 patients with isolated aortic valve disease (iAVR) (mean age, 70 ± 13 years; 59% were male) underwent operation at Yale-New Haven Hospital by 1 surgeon (JAE) and met the criteria of the present study. Among those, 81 pairs were matched for comparison using the propensity score model. The demographic and medical characteristics are presented in Table 1.

Subgroup Population

Among the 182 patients undergoing the concomitant AVR and RS procedure, 96 underwent an open distal anastomosis using DHCA and 86 received an approach limited to the ascending aorta without the need for DHCA. To compare outcomes for these 2 subgroups, we used matching techniques on them. Among those groups, 71 patients each matched for comparison using the propensity score model were included in the analysis. Demographics and characteristics are shown in Table 1.

Surgical Indication and Procedure

According to guidelines, a diameter of 45 mm represents the indication to concomitantly replace the aorta in case of an indicated cardiac procedure at the Aortic Institute.[7] None of the patients in the iAVR group met this criterion. In the RS group, the aorta was replaced at a diameter of 45 mm or greater in 111 patients, 40 to 44 mm in 19 patients, and less than 40 mm in 6 patients, according to our institutional policy regarding co-incidental diseases and biometrical adjustment.[8,9]

All procedures were performed using a total median sternotomy. The aortic valve was implanted by an intra-annular technique, and the ascending aorta, if applicable, was resected above the aortic valve commissures. An open distal anastomosis was distinguished by the lack of supra-aortic branch disconnection and reimplantation. If circulatory arrest was applicable, deep core temperatures approaching 18°C to 19°C were used, followed by an extended warming. No adjunct selective organ perfusion technique was used.

Statistical Analysis

The matching between the respective groups was done by using a propensity score model including the following variables: age, gender, aortic valve stenosis, bicuspid valve morphology, symptomatic disease, arterial hypertension, pulmonary hypertension, left ventricular ejection fraction 35% or less, coronary artery disease, atrial fibrillation, history of smoking, chronic obstructive pulmonary disease, diabetes, chronic renal failure, hemodialysis, and history of stroke. The propensity score model was matched using nearest neighbor matching with a caliper of 0.25. Matching covariates and standardized difference of the mean are shown in Figure 1 and Table E1.

Data are presented as frequency distributions and percentages for categoric variables or as mean ± standard deviation for continuous variables. The Pearson chi-square test or Fisher exact test was used when analyzing categoric variables, the Student *t* test or Mann–Whitney *U* test was used for continuous variables, and the Kaplan–Meier survival estimate was used for survival analysis. The Gehan–Breslow–Wilcoxon test (for detecting significance mostly in the earlier time period) was used to compare the estimated survival of different populations. Statistical analysis and matching were performed using SPSS version

TABLE 1. Demographics and characteristics

	Propensity score–matched cohort					
	iAVR	AVR + RS		Clamped anastomosis	Open distal anastomosis	
n =	81	81	*P* value	71	71	*P* value
Age, y	63.5 ± 13.6	63.1 ± 11.2	.821	60.4 ± 11.6	60.0 ± 13.3	.861
Male gender	55 (68%)	56 (69%)	1.000	48 (68%)	46 (65%)	.859
BMI	28.1 ± 5.2	28.2 ± 5.9	.848	29.5 ± 6.4	28.3 ± 5.9	.291
STS risk score						
Operative mortality, %	1.15 ± 0.88	1.07 ± 0.66	.515	0.92 ± 0.55	0.99 ± 0.62	.458
Major morbidity or operative mortality, %	10.15 ± 3.43	10.17 ± 3.3	.972	9.38 ± 2.94	9.73 ± 2.88	.472
Aortic valve disease						
Stenosis	63 (78%)	53 (65%)	.116	44 (62%)	39 (55%)	.496
Mean pressure gradient, mm Hg	48.7 ± 13.7	41.1 ± 15.6	**.014**	44.5 ± 17.2	38.9 ± 17.0	.188
Valve area, cm^2	0.72 ± 0.16	0.90 ± 0.34	**.002**	0.85 ± 0.25	0.97 ± 0.39	.140
Insufficiency	18 (22%)	28 (35%)	.116	27 (38%)	32 (45%)	.496
Valve morphology						
Bicuspid	56 (69%)	56 (69%)	1.000	58 (82%)	52 (73%)	.315
Aortic diameter						
Root	33.8 ± 5.3	35.9 ± 6.2	.112	37.4 ± 6.7	36.9 ± 5.9	.729
Ascending	34.8 ± 4.4	48.5 ± 7.6	**<.001**	46.4 ± 5.8	50.6 ± 7.6	**<.001**
Arch	27.9 ± 3.7	28.9 ± 5.0	.409	28.9 ± 5.1	30.6 ± 5.5	.237
Bovine arch	0 (-)	4 (5%)	.120	1 (1%)	6 (9%)	.116
Comorbidities						
Symptomatic	70 (86%)	63 (78%)	.218	44 (62%)	43 (61%)	1.000
Arterial HT	59 (73%)	66 (82%)	.261	56 (79%)	55 (78%)	1.000
Pulmonary HT	5 (6%)	5 (6%)	1.000	0 (-)	0 (-)	-
LVEF	56.8 ± 12.1	56.8 ± 10.4	.977	58.1 ± 9.6	57.8 ± 8.6	.833
Coronary artery disease	10 (12%)	10 (12%)	1.000	6 (9%)	8 (11%)	.779
Atrial fibrillation	7 (9%)	7 (9%)	1.000	5 (7%)	6 (9%)	1.000
History of smoking	32 (40%)	26 (32%)	.413	20 (28%)	23 (32%)	.715
COPD	11 (14%)	6 (7%)	.305	5 (7%)	4 (6%)	1.000
Dyslipidemia	46 (57%)	43 (53%)	.752	40 (56%)	39 (55%)	1.000
Diabetes	13 (16%)	14 (17%)	1.000	10 (14%)	12 (17%)	.817
Chronic renal failure	5 (6%)	4 (5%)	1.000	1 (1%)	2 (3%)	1.000
Creatinine	0.91 ± 0.28	0.89 ± 0.23	.373	0.86 ± 0.21	0.91 ± 0.23	.156
History of stroke	4 (5%)	4 (5%)	1.000	2 (3%)	3 (4%)	1.000

Data are shown as mean ± standard deviation, number (percentage) or as [reported]. Bold values are statistically significant ($P < .05$). *iAVR*, Isolated aortic valve replacement; *AVR*, aortic valve replacement; *RS*, root-sparing; *BMI*, body mass index; *STS*, Society of Thoracic Surgeons; *HT*, hypertension; *LVEF*, left ventricular ejection fraction; *COPD*, chronic obstructive pulmonary disease.

23.0 (IBM Inc, Armonk, NY) in cooperation with the Departments of Economics and Preventive Medicine of Stony Brook University (Stony Brook, NY).

RESULTS

Operative Data

In the propensity score–corrected population, cardiopulmonary bypass times were 91.1 ± 14.4 minutes (iAVR) and 144.1 ± 25.7 minutes (RS) ($P < .001$), and crossclamp times were 68.0 ± 11.7 minutes (iAVR) and 99.8 ± 13.9 minutes (RS) ($P < .001$), and thus differ by 53 and 32 minutes. Distal anastomosis was performed open in 53% of the patients, requiring 25.9 ± 3.7 minutes of circulatory arrest at 19.1°C ± 0.8°C on average. No additional selective cerebral perfusion strategy was used according to our institutional protocol.[10] Technical complications were noted in 3% of patients (RS) and 1% of patients (iAVR), in the majority of the cases represented by a secondary change of the valve prosthesis to a smaller size or reconstruction of the femoral artery due to arterial cannulation. Further operative details are noted in the Appendix (Table 2).

Postoperative Outcome

Among the propensity score–corrected comparison, patients undergoing concomitant aortic surgery experienced a higher incidence of prolonged ventilation (7% vs 0%, $P = .028$) and longer stay in the intensive care unit (3.7 ± 3.5 days vs 2.8 ± 1.5 days, $P = .025$). In-hospital

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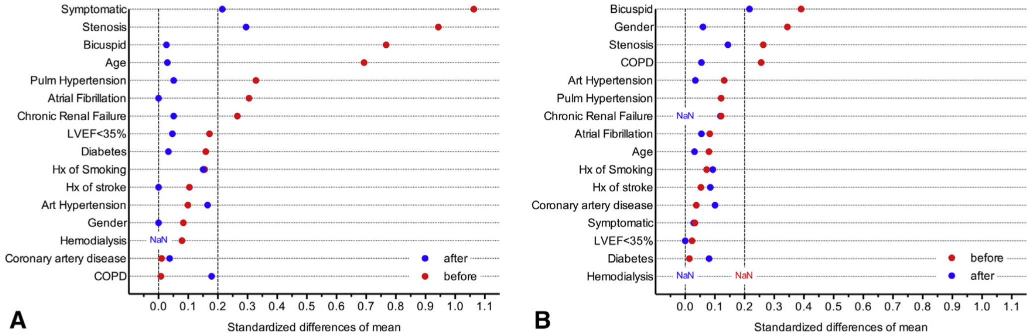

FIGURE 1. Covariate balance for (A) study analysis and (B) subgroup analysis before and after propensity score matching. *pulm*, Pulmonary; *LVEF*, left ventricular ejection fraction; *hx*, history; *Art*, arterial; *COPD*, chronic obstructive pulmonary disease.

stay and other comorbidities, such as bleeding, renal failure, and stroke, showed no difference between the groups. Operative mortality was 0% in both groups. Details are shown in Table 3.

Follow-up and Survival

Survival expressed by the Kaplan–Meier survival estimation in Figure 2 showed no significant difference between the groups ($P = .7237$).

During follow-up, no patient in the RS group required a secondary root replacement due to progressive root dilation; only 1 patient had a pseudoaneurysm of the suture line (infection) and underwent redo ascending replacement 4 months after prior surgery.

Mean follow-up time was 4.7 ± 3.4 years (RS) and 4.9 ± 3.4 years (iAVR). No significant differences were found in late complications regarding secondary aortic valve replacement, complete heart block, pericardial and pleural effusion, left ventricular ejection fraction decline, need for automated implantable cardioverter-defibrillator, transitory ischemic attack, stroke, endocarditis, renal failure, patient–prosthesis mismatch, or structural and nonstructural prosthesis deterioration after discharge.

Distal Anastomosis Technique (Subgroup Analysis)

The subgroup analysis of the concomitant RS ascending replacement cases, divided according to the type of distal

TABLE 2. Operative data

	Propensity score–matched cohort					
	iAVR	AVR + RS	*P* value	Clamped anastomosis	Open distal anastomosis	*P* value
CPB time, min	91.1 ± 14.4	144.1 ± 25.7	**<.001**	127.3 ± 16.3	159.9 ± 18.8	**<.001**
Crossclamp time, min	68.0 ± 11.7	99.8 ± 13.9	**<.001**	103.3 ± 14.2	98.6 ± 15.4	.066
DHCA	0 (-)	43 (53%)	**<.001**	0 (-)	71 (100%)	**<.001**
DHCA time, min	-	25.9 ± 3.7	-	-	25.6 ± 4.9	-
Lowest core temperature, °C	-	19.1 ± 0.8	-	-	18.9 ± 0.6	-
Arterial cannulation						
Ascending aorta/arch	81 (100%)	10 (12%)	**<.001**	9 (13%)	3 (4%)	.129
Femoral artery	0 (-)	67 (83%)	**<.001**	61 (86%)	66 (93%)	.275
Axillary artery	0 (-)	4 (5%)	.120	1 (1%)	2 (3%)	1.000
Prosthesis						
Mechanical	39 (48%)	34 (42%)	.528	35 (49%)	35 (49%)	1.000
Biological	42 (52%)	47 (58%)		36 (51%)	36 (51%)	
Size, mm	21.6 ± 2.2	22.3 ± 2.0	**.049**	22.5 ± 2.0	22.5 ± 2.2	.967
Primary procedure						
RS technique	-	81 (100%)	-	71 (100%)	71 (100%)	-
Open distal anastomosis	-	43 (53%)	-	0 (-)	71 (100%)	-
Concomitant procedure	9 (11%)	15 (19%)	.269	12 (17%)	11 (16%)	1.000
Annuloplasty	1 (1%)	0 (-)	1.000	0 (-)	0 (-)	-
Technical complication	1 (1%)	2 (3%)	1.000	3 (4%)	4 (6%)	1.000

Data are shown as mean ± standard deviation, number (percentage) or as [reported]. Bold values are statistically significant ($P < .05$). *iAVR*, Isolated aortic valve replacement; *AVR*, aortic valve replacement; *RS*, root-sparing; *CPB*, cardiopulmonary bypass; *DHCA*, deep hypothermic circulatory arrest.

TABLE 3. Early postoperative outcome

	Propensity score–matched cohort					
	iAVR	**AVR + RS**	***P* value**	**Clamped anastomosis**	**Open distal anastomosis**	***P* value**
Reexploration due to bleeding	5 (6%)	4 (5%)	1.000	4 (6%)	3 (4%)	1.000
Morbidity						
Ventilation >48 h	0 (-)	6 (7%)	**.028**	2 (3%)	5 (7%)	.441
LCOS	0 (-)	1 (1%)	1.000	1 (1%)	1 (1%)	1.000
With IABP	3 (4%)	3 (4%)	1.000	1 (1%)	1 (1%)	1.000
With ECLS/ECMO	0 (-)	1 (1%)	1.000	0 (-)	1 (1%)	1.000
Myocardial infarction	0 (-)	1 (1%)	1.000	0 (-)	1 (1%)	1.000
Atrial fibrillation*	9 (11%)	7 (9%)	.793	6 (9%)	5 (7%)	1.000
AV block III*	7 (9%)	4 (5%)	.534	4 (6%)	6 (9%)	.745
Pacemaker	10 (12%)	4 (5%)	.160	4 (6%)	6 (9%)	.745
Renal failure*	4 (5%)	4 (5%)	1.000	2 (3%)	3 (4%)	1.000
Stroke	1 (1%)	1 (1%)	1.000	0 (-)	1 (1%)	1.000
Infection	6 (7%)	5 (6%)	1.000	2 (3%)	2 (3%)	1.000
Sepsis	0 (-)	0 (-)	-	0 (-)	0 (-)	-
Composite morbidity†	10 (12%)	11 (14%)	1.000	8 (11%)	10 (14%)	.802
Length of stay						
ICU, d	2.8 ± 1.5	3.7 ± 3.5	**.025**	2.9 ± 1.4	3.5 ± 3.0	.143
Median (25-75 percentile)	3.0 (2.0-3.0)	3.0 (2.0-4.0)	**.029**	2.0 (2.0-3.0)	3.0 (2.0-4.0)	.323
In-hospital, d	5.9 ± 1.9	6.4 ± 4.0	.321	5.6 ± 1.3	6.1 ± 3.6	.231
Median (25-75 percentile)	5.0 (5.0-6.0)	5.0 (5.0-6.0)	.520	5.0 (5.0-6.0)	5.0 (5.0-6.0)	.596
Operative mortality‡	0 (-)	0 (-)	-	0 (-)	0 (-)	-
1-y survival, %	97.3 ± 1.9	98.8 ± 1.2		100 ± 0	98.6 ± 1.4	
5-y survival, %	88.3 ± 4.3	92.8 ± 3.1		98.4 ± 1.6	95.6 ± 2.5	

Data are shown as mean ± standard deviation, number (percentage) or as [reported]. Bold values are statistically significant ($P < .05$). *iAVR*, Isolated aortic valve replacement; *AVR*, aortic valve replacement; *RS*, root-sparing; *LCOS*, low cardiac output syndrome; *IABP*, intra-aortic balloon pump; *ECLS*, extracorporeal life support; *ECMO*, extracorporeal membrane oxygenation; *AV*, aortic valve; *ICU*, intensive care unit. *Postoperative new-onset. †Including reexploration, prolonged ventilation, stroke, renal failure, low cardiac output syndrome, and sepsis. ‡Classified as in-hospital mortality plus 30-day mortality of discharged patients; length of stay refers to the postoperative period.

anastomosis (open and with DHCA or clamped and without DHCA), showed no significant differences in the postoperative morbidity, mortality, and length of stay. The stroke rate was low in both subgroups, with 0% (an approach limited to the ascending aorta without the need for DHCA) and 1% (open distal anastomosis using DHCA). Midterm analysis showed comparable survival in patients who underwent open extension with DHCA compared with those with a clamped distal anastomosis in midterm view ($P = .0533$). However, long-term survival differed significantly between the distal anastomosis type groups, from year 5 onward (log rank [Mantel–Cox] test: $P = .0213$). Survival is shown in Figure 3, and further details are outlined in Tables 2 and 3.

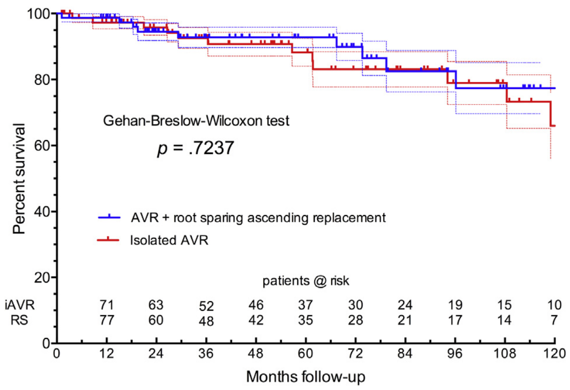

FIGURE 2. Kaplan–Meier survival estimation after propensity score matching of the concomitant RS aortic replacement group compared with the control group undergoing an iAVR approach. *AVR*, Aortic valve replacement; *iAVR*, isolated aortic valve replacement; *RS*, root sparing.

DISCUSSION

Aortic valve disease and ascending aortic aneurysm are often associated with various causes. In addition to hemodynamic flow patterns with aberrant mechanical forces causing a poststenotic aortic dilation, intrinsic genetic and physiologic abnormalities of the aortic wall are known to be at play (eg, Marfan disease, bicuspid aortic valves).[9] Moreover, an aneurysm of the aorta itself can cause aortic valve insufficiency by dilating the valve scaffold and reducing the coaptation area of the cusps. In case of the co-incidence of both diseases (diseased aortic valve and aorta), it still remains controversial whether a more preventive approach or a more restrained posture regarding the aorta is indicated.[11] Opponents of an aggressive

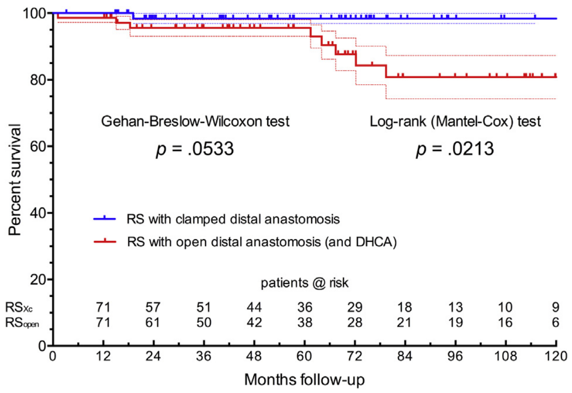

FIGURE 3. Kaplan–Meier survival estimation after propensity score matching comparing clamped technique for distal site and open distal anastomosis (with DHCA). *RS*, Root-sparing; *DHCA*, deep hypothermic circulatory arrest; RS_{Xc}, approach limited to the ascending aorta without the need for DHCA; RS_{open}, open distal anastomosis using DHCA.

approach argue that a concomitant aortic replacement increases the operative risk compared with an isolated valve replacement.

This study shows that adding an RS ascending aortic replacement—representing the surgically simplest approach regarding the proximal anastomosis of the diseased aorta—is associated with no higher operative risk than an iAVR. In fact, this risk was 0%. The overall incidence of postoperative morbidity also was low, especially regarding the reexploration rate (4%) and postoperative strokes (1%). Only a higher incidence of prolonged ventilation (7% vs 0%) was found. Intensive care unit and in-hospital stays were brief (2-4 and 5-6 days, respectively). None of the patients with concomitant aortic surgery died within 30 days.

Studies from the University of Virginia, University of Toronto, Northwestern University, and, most recently, University of Udine, focusing on bicuspid valves, presented similarly favorable results and confirm the safety of the RS approach found in the present study.[12-15]

Even by extending the surgical approach close to or into the arch portion (with an open distal anastomosis and the need for DHCA), the postoperative outcomes remained favorable, with a mortality of 0%. Because of the more complex operative approach, a slightly higher incidence of prolonged ventilation (5%-7% vs 3%-4%), renal failure (4% vs 2%-3%), and postoperative need for antibiotic treatment (infection 3%-5% vs 2%-3%) were found. An open distal anastomosis represents an entirely resected ascending portion without remaining residual. We think the open distal anastomosis is a technically easier approach, reflected by a decreased crossclamp time of 4 to 5 minutes (Table 2). However, this technique also requires hypothermic circulatory arrest with a consequently prolonged time on cardiopulmonary bypass due to cooling and rewarming (32-33 minutes in the present study) and the necessity of a cerebral protection strategy.

At our institution, straight deep hypothermic arrest (targeting 18°C-19°C) represents the established routine of brain and organ protection. In a former study by our group, Gega and colleagues[16] found a stroke rate of 2.3% and mortality of 2.0% in elective cases using this technique. Later, Ziganshin and colleagues[10] confirmed these good results, analyzing arch replacements and reporting strokes in 1.2% and early mortality in 1.4% of the cases, one third due to cerebral-associated causes. The safe duration of DHCA was evaluated as within 40 and 50 minutes in these studies. In comparison with adjunct brain protection techniques, straight DHCA was found as effective as more complex perfusion approaches and furthermore provides an unimpaired surgical view by the lack of additional perfusion catheters in or cannulas close by the operative field.[17,18] In the present study, the mean time of DHCA was completely within the safe period, lasting 25 to 26 minutes on average, with a range from 11 to 46 minutes. Femoral cannulation represents our standard technique and provides simplicity and effectiveness.[19,20] We reserve an axillary approach for cases with a ‘‘dirty’’ aorta on preoperative computed tomography or intraoperative transesophageal echocardiography.

Is sparing the root and leaving a portion of the very proximal native aortic tissue a sufficient approach or do we risk the manifestation of root aneurysms later? Replacing the root as a redo procedure certainly is associated with an appreciable operative risk and mortality. By analyzing the biomechanical parameters of a spared root, Simon-Kupilik and coworkers[21] found a significant increase of hemodynamic burden after ascending graft replacement. They reported an increase in the wall stress index in the native root of 22% (in vitro) and 16% (in vivo). Rinewalt and colleagues[12] advocated a more aggressive intervention, recommending Bentall procedures to avoid reoperations. However, in our opinion, sparing the root is a legitimate technique for 2 reasons: First, a replacement of the root requiring reimplantation of the coronary arteries is associated with a slightly higher operative risk.[2] In a large meta-analysis, Castrovinci and colleagues[22] found a stroke rate of 3.7% (range, 0%-29%), myocardial infarction rate of 2.9% (range, 0%-13%), and bleeding complications requiring operative reexploration rate of 7.6% (range, 0%-27%). In-hospital mortality was 6.4% (range, 0%-25%). Second, the aortic root grows slowly, slower than the other portions of the aorta. In a recent analysis from our institution, the growth rate was found at 0.41 mm per year (range, 0.27-0.51 mm/year according to the initial diameter

[25-50 mm]), regardless of valve morphology or concomitant valve replacement. We calculated (on the basis of a comparable mean root diameter as in the present study) and according to our institutional criteria (root replacement at 50 mm) that subsequent aortic root replacement would not be required for 29 years or more.[23] The most recent findings of Vendramin and coworkers[15] clinically support these data.

As mentioned in the beginning of this article, the separation of benefit from harm is essential but difficult. It still remains controversial in the literature which aortic diameter triggers the surgical decision for aortic intervention in cases of primary aortic valve disease. Also controversial is whether bicuspid valve morphology indicates a resection at earlier stages.[11,24-28] Verma and colleagues[11] analyzed (using a survey) the variety of aortic treatments in the presence of bicuspid valve morphology among Canada's adult cardiac surgeons. They found that the threshold for resection the aorta in case of a nondiseased bicuspid valve was 55% at 50 mm and 23% at 45 mm, whereas a diseased valve lowers the threshold to 45 mm in 61% and to 40 mm in 29% of the surgeons' decisions. However, the good results reported in the current article and others[12-15] for the RS approach advocate for a more liberal treatment in elective patients.

Despite our institutional policy and the guidelines recommending concomitant aortic replacement at a diameter of 45 mm (Class I, evidence level B),[29] it must be recognized that the risk of subsequent aortic events after iAVR consistently has been low. In patients presenting with a diameter larger than 40 mm during initial iAVR, McKellar and colleagues[30] from the Mayo Clinic found (analyzing exclusively bicuspid morphologies) only slightly less freedom from aortic events (aortic dissection, surgery, and enlargement) of 75% to 85% within 15 years, compared with those with smaller diameter (88%-93% freedom). In a recent study neglecting initial diameter, Itagaki and colleagues[31] from the Mount Sinai group reported a generally low incidence of aortic-related diseases after iAVR. The 15-year cumulative incidence of aortic dissection, aortic aneurysm, and the need for thoracic aortic surgery was 0.6%, 4.8%, and 2.5%, respectively, for patients with bicuspid valve morphology and 0.4%, 1.4%, and 0.5%, respectively, for nonbicuspid and non-Marfan cases. Following the current guidelines, no aortic event (aortic dissection or need for thoracic aortic surgery) occurred in our patients undergoing iAVR during follow-up in the present study. We have shown that concomitant aortic surgery can be performed safely, but we have not proven that this was necessary.

Study Limitations

This is a retrospective study with the inherent limitations for such an analysis. We caution regarding the extrapolation of our results to higher-risk older patients. Also, we used a single cutoff value (45 mm ascending diameter) for the decision to resect the ascending aorta. Although this cutoff, representing our institutional policy, is consistent with guidelines,[29] our study cannot determine the appropriate criterion (eg, in the range of 40-50 mm) for concomitant aortic resection at the time of AVR. A randomized study would be necessary to focus on diameters between 40 and 50 mm, including cofactors such as height, family history of dissection/rupture, connective tissue disorders, valve morphology, and other "associations."[9] This study represents a single-surgeon observation. Although such types of patient cohorts are limited in number and thus the potential number after matching is limited, it also provides uniformity in decision making, treatment, surgical quality, and clinical experience, which may counterbalance the detriments. Despite these limitations in statistical criteria and variables, we should not lose track of the main findings of this study: The technical performance of incremental concomitant supracoronary aortic replacement can be accomplished at a low surgical risk (0% in this study).

CONCLUSIONS

Concomitant aortic valve and RS aortic replacement can be performed as safely as an iAVR in elective patients. If an extension close to or into the arch portion is advised, the operative mortality is still low and morbidity is slightly higher, but survival remains comparable. Thus, in experienced centers, an RS ascending replacement in aneurysmal patients, without a dilated aortic root and without syndromic connective tissue disorder, can be performed in addition to AVR without hesitation; furthermore, an open distal anastomosis, if necessary, should not be ruled out.

Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

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Key Words: aneurysm, aortic root, aortic valve replacement, surgical risk

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TABLE E1. Matching model results

	Propensity score–matched cohort	
	Study analysis	**Subgroup analysis**
n per group =	**81**	**71**
Age	0.030	0.031
Male gender	0	0.060
Aortic valve disease		
Stenosis	0.295	0.144
Valve morphology		
Bicuspid	0.027	0.217
Comorbidities		
Symptomatic	0.215	0.029
Arterial HT	0.166	0.034
Pulmonary HT	0.051	NA
LVEF ≤35%	0.047	0
Coronary artery disease	0.037	0.101
Atrial fibrillation	0	0.055
History of smoking	0.151	0.093
COPD	0.179	0.055
Diabetes	0.033	0.080
Chronic renal failure	0.051	0.119
Hemodialysis	NA	NA
History of stroke	0	0.085

Data are shown as standardized difference of the mean. *HT*, Hypertension; *LVEF*, left ventricular ejection fraction; *COPD*, chronic obstructive pulmonary disease; *NA*, not applicable.

5.2 The aortic root: Natural history after root-sparing ascending replacement in nonsyndromic aneurysmal patients.

The Aortic Root: Natural History After Root-Sparing Ascending Replacement in Nonsyndromic Aneurysmal Patients

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Background. **Leaving native aortic tissue in situ in root-sparing ascending aortic replacement raises concern regarding potential later need for root reoperation or for the potential occurrence of localized dissections or rupture in the residual root. The purpose of this study was to evaluate the natural growth of the aortic root after root-sparing aortic replacement.**

Methods. **In all, 102 consecutive patients (mean age 61.8 ± 12.5 years; 60% male) who had undergone root-sparing aortic replacement had sufficient retrievable information regarding their aortic root diameter at postoperative baseline and follow-up imaging by computed tomography or echocardiography. The annual growth rate was evaluated and also compared according to the influence of valve morphology and concomitant aortic valve replacement. Furthermore, the years of natural history that would require for root enlargement to meet a 50 mm threshold of the root diameter were calculated.**

Results. **The estimated growth rate of the aortic root after root-sparing aortic replacement is between 0.27 and 0.51 mm per year (mean 0.41 mm, varying according to the underlying diameter) and therefore fivefold less than other aortic regions. Accordingly, a root aneurysm indicating reoperation would not be expected for 29.1 years on average. Only patients with a diameter of 45 mm or more are at risk for reoperation, and not until at least after 10.4 years have passed. Neither the valve morphology ($p = 0.62$) nor concomitant aortic valve replacement ($p = 0.86$) influenced rate of root dilation.**

Conclusions. **In nonsyndromic patients, the aortic root is the slowest growing portion of the thoracic aorta. Leaving the native root, as in root-sparing ascending aortic replacement, is a safe approach regarding secondary root intervention for aortic root diameters of 45 mm or less.**

(Ann Thorac Surg 2017;103:828–33)

The incidence of thoracic aortic aneurysms has been determined to be approximately 6 to 15 cases per 100,000 patient-years [1–3]. Approximately 60% of the aneurysms involve proximally the aortic root or ascending portion, 10% the aortic arch, 40% the descending, and 10% the thoracoabdominal region (some patients have dilations at more than one level) [4]. Aortic dissection and rupture are the most devastating natural complications of aortic aneurysm, and data from our group revealed aneurysm size to be an important predictor in the course of these events [5]. Whereas the international guidelines follow a more conservative approach (recommending replacement at 55 mm in case of the proximal aortic regions [6–8]), most specialized centers tend to intervene on the proximal aorta at somewhat smaller sizes.

It still remains controversial at which size a proactive replacement of a specific portion of the aorta is indicated and how extensive the resection should be, especially in case of the aortic root [9]. Sparing a nondilated or slightly dilated root during an ascending replacement simplifies the surgical technique, but concern exists when leaving the native root in situ with regard to further, future dilation. The concerns surround possible dissection and rupture in the residual root segment or potential need for reoperation for progressive dilation.

Despite these concerns, the specific growth dynamic of the root is not well reported for nonsyndromic (for example, non–Marfan syndrome) patients in the literature. The aim of this study was to quantify the natural

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growth of the residual nonaneurysmal aortic root portion after root-sparing ascending aortic replacement. We also aimed to estimate the interval until a reoperation after a root-sparing approach might be necessary. Furthermore, we tried to determine the influence of concomitant aortic valve replacement (AVR) and of different valve morphologies on the dilation progress.

Patients and Methods

Study Design

To determine the natural growth rate of the aortic root, we analyzed postoperative inner root diameters in patients who received root-sparing/supracoronary ascending replacements, and determined rates according to initial root size. Further subanalyses were performed to evaluate a possible stabilizing effect of a concomitant AVR on the growth rate of the root and any potential impact of the natural aortic valve morphology.

The study was approved by the Human Investigation Committee of the Yale University School of Medicine. All patients gave written informed consent for participation in the study.

Inclusion Criteria

All consecutive patients undergoing a root-sparing/supracoronary ascending aortic replacement at the Yale Aortic Institute between 2004 and 2011 were retrospectively reviewed in this study. Patients with two or more retrievable images or evaluable transparent measurements were included. Postoperative imaging assessments were done according to Institute policy regarding follow-up consultations and images. Patients after 2011 were excluded both to prevent measurement errors from short follow-up (due to an expected slow growth rate) and to ensure identifying secondary aortic root dilation. Within this time frame, a total of 366 aneurysm patients underwent elective ascending aortic replacement by a root-sparing technique and were reviewed according to the inclusion criteria. Contemporaneously, a root replacement was performed in 239 aneurysm patients [10].

Exclusion Criteria

According to the aim of the study, the following exclusion criteria were defined: root remodeling/replacement operation (any type), syndromic genetic disorders (Marfan syndrome, Ehlers-Danlos, and others), aortic dissections, intramural hematomas, and redo cardiac operations.

Data Collection and Analysis

This study was performed retrospectively. To determine growth rates, baseline computed tomography (CT) or echocardiography imaging was reviewed for all patients after surgery and compared with subsequent available imaging studies. Aortic root variables were measured by two cardiac surgeons independently (J.A.E. and S.P.) and evaluated from imaging reports (if those reported separately sizes for the annulus, sinus of Valsalva, sinotubular junction, and ascending aorta) from Department of Radiology or Department of Cardiology at Yale–New Haven Hospital. For quality control, repetitive blinded and randomly assigned reviews were performed in 100 imaging studies (31.8%). If an interobserver discrepancy greater than 5% was detected (between measurements of the two surgeons, or between the surgeons' measurements and the radiology reports), for each such patient a collaborative decision was reached between the surgeons and the radiologists regarding the size of the aorta to include in the study (12.4%; 14 of 113 identified patients) [11]. Owing to the known and identified interobserver differences in evaluating the aortic root sizes by either of theses modalities and to enhance transparency of the taken measures, reports from outside institutions were excluded. The impact of imaging modality—echocardiography (12.4%; 14 of 113) or CT (87.6%; 99 of 113)—was tested and was highly insignificant ($p = 0.54$). Therefore, the modality had virtually no effect on the other estimated coefficients of the growth model in the present study.

The measurements were taken at the maximum inner diameter of the sinus of Valsalva and compared with later measurements by the same modality in the same planes (because of the known differences between ultrasonographic and radiographic evaluation) [12]. With regard to the surgical procedure—ascending aortic replacement with or without AVR—measurements at the annulus and sinotubular junction were renounced owing to proximity of the anastomosis site.

We also calculated the number of years needed to reach 50 mm and 55 mm intervention thresholds. However, according to our institutional policy, indication for operative repair of aortic root aneurysm (in an asymptomatic patient) is a diameter greater than 45 mm, or an annual dilation of 5 mm or more (very rare), except in higher risk patients or if contraindications exist.

Statistical Analyses

As described previously by our group, we analyzed the growth rate of the aortic root by performing a multivariate regression analysis to estimate the growth pattern [13, 14]. Further details are reported in the Appendix.

Results

Patient Population and Follow-Up

Between 2004 and 2011, 113 patients underwent elective ascending aortic replacement by a root-sparing technique and fulfilled the inclusion and exclusion criteria. Among these, 9 patients were excluded owing to incomplete follow-up data by collaborative decision round and another 2 patients were determined to be outliers with observed aortic measurements greater than two standard deviations from the mean by our statistical experts. Therefore, the final cohort in this study consisted of 102 patients. However, as a number of patients had more than one imaging studies, 199 observations (change in aortic size between two images) were available for statistical analysis. Mean time between $Image_{T-1}$ and $Image_T$ was 19.55 ± 16.52 months (range, 0 months to 8.75 years), and between first postoperative and most recent image, 41.62 ± 26.08 months (range, 2 months to 9.17 years). Patient demographics, characteristics, and comorbidities are depicted in Table 1.

Surgical Data

The proximal ascending aorta was replaced in all patients by a root-sparing technique; 66 of those (63.7%) received a concomitant AVR. In the distal ascending portion, 74 patients (72.5%) underwent extension into the arch under deep hypothermic circulatory arrest. Among those, the hemiarch was replaced in 60 (58.8% of all patients) and the total arch in 14 (13.7% of all patents). An elephant trunk stage-1 procedure was performed in 11 patients (10.8% of all patients). Sixteen patients (16%) underwent concomitant coronary artery bypass graft surgery.

Aortic Root Diameter and Growth Rate

The mean postoperative baseline diameter was 37.4 ± 3.76 mm (range, 27 to 48 mm), evaluated 5.63 ± 1.29 months postoperatively on average. Owing to inclusion of longitudinal observations, mean sizes at $Image_T$ and $Image_{T-1}$ were 38.79 ± 3.55 mm (range, 28 to 48 mm) and 38.20 ± 3.51 mm (range, 27 to 47 mm), respectively. In multivariate regression analysis, the coefficient on *TIME* was positive (0.000652) and highly significant ($p < 0.0001$). That indicates that the aortic root does grow over time. Mean growth rate is estimated at 0.41 mm per year (95% confidence interval: 0.35 to 0.46 mm per year). According to initial root size, the growth rate increases with larger diameter (Table 2, Fig 1). The time interval until 50 mm would be reached would be 29.1 years on average (Fig 2).

Table 1. Preoperative Patient Data

Measures	Study Group (n = 102)
Demographics	
Age, years	61.8 ± 12.5
Male	61 (59.8)
Characteristics	
Weight, kg	85.1 ± 19.1
Height, cm	172.0 ± 10.5
Body mass index, kg/m^2	28.6 ± 5.2
Root, initial diameter, mm	37.4 ± 3.8
Aortic valve pathology	
Stenosis	35 (34.3)
Insufficiency	36 (35.2)
Ratio	0.97:1
Bicuspid morphology	47 (46)
Comorbidities	
Coronary artery disease	23 (22.5)
Arterial hypertension	86 (84.3)
Dyslipidemia	50 (49.0)
Diabetes mellitus	7 (6.9)
Chronic renal failure	3 (2.9)
History of stroke	4 (3.9)
History of smoking	26 (25.5)

Values are mean ± standard deviation or n (%).

Effect of Contemporaneous AVR and Valve Morphology on Root

The dilation of the root is estimated respectively at 0.40 mm per year on average with concomitant AVR and at 0.42 mm per year on average without AVR. The coefficient on the interaction term *AVR*TIME* in multivariate regression analysis is small (−0.0000230) and insignificant ($p = 0.86$). These findings indicate that growth in the aortic root is unaffected by concomitant AVR after the root-sparing operation.

The distribution by native aortic valve morphology showed dilation of 0.42 mm per year for bicuspid valves and of 0.40 mm per year for tricuspid valves on average. The coefficient on the interaction term *BAV*TIME* is also small (0.0000593) and insignificant ($p = 0.62$). Data are summarized in Table 3.

Follow-Up

The mean clinical follow-up period was 72.0 ± 30.9 months (median 71.9; range, 13.9 to 143.8). One-year, 5-year, and 10-year survival estimation was 100%, 94.4% ± 2.5%, and 85.3% ± 5.3%, respectively. In total, 4 patients (3.9%) required aortic or aortic valve reoperation during follow-up. One of those each underwent AVR (because of endocarditis), arch replacement with elephant trunk stage-1 procedure, open descending aortic replacement, and abdominal aortic replacement. No patient required replacement of the primarily untouched root or had dissection of the proximal aorta. Freedom from aortic/aortic valve reoperation was 100%, 96.6% ± 1.9%, and 93.9% ± 3.2% at 1, 5, and 10 years, respectively; and freedom from aortic root events (aortic root replacement, aneurysm, or dissection of the untouched root) was 100% each at 1, 5, and 10 years.

Comment

Growth Behavior of Aortic Root and Other Portions

The aortic root, defined anatomically by the scaffold of the valve leaflets (aortic annulus) inferiorly and by the sinotubular junction superiorly, grows on average 0.41 mm per year after root-sparing aortic replacement. Other portions of the aorta show a considerably higher growth rate. In a recent study from our group, we evaluated the growth rates from our institutional database at the Aortic Institute at Yale–New Haven and found a growth rate of 2.0 mm per year in the ascending and arch portion, 2.26 mm per year in the descending aorta, and 2.3 mm per year in the thoracoabdominal sector (data are displayed in Fig 1) [15]. The dilation over time in these portions also increases with larger diameter. Given these preliminary data, the results of the present study indicate that the aortic root dilates at a rate almost fivefold less than all other parts of the aorta at the same size.

Table 2. Estimated Average Annual Growth Rates of Aortic Root by Initial Size

	Annual Growth Rate (mm per year)				
Initial Aortic Size	Total Cohort (n = 102)	No AVR (n = 36)	AVR (n = 66)	BV Morphology (n = 47)	TV Morphology (n = 55)
25 mm	0.27	0.27	0.26	0.28	0.26
30 mm	0.32	0.33	0.31	0.33	0.31
35 mm	0.37	0.38	0.35	0.39	0.36
40 mm	0.43	0.43	0.42	0.44	0.41
45 mm	0.48	0.49	0.48	0.50	0.47
50 mm	0.51	0.54	0.53	0.55	0.52
Mean, 37.3 mm	0.41	0.42	0.40	0.42	0.40

AVR = aortic valve replacement; BV = bicuspid valve; TV = tricuspid valve.

Although the macroscopic morphology of the aorta suggests a continuous and homogeneous network of tissue, the aorta is actually composed of distinct microscopic structures. The regional heterogeneity begins during embryogenesis [16, 17] and impacts the elasticity determining aortic media. The aortic media tunic, impaired by the remodeling process in aneurysms, consists of elastin, collagen, and vascular smooth muscle cells. These smooth muscle cells, derived from different embryologic origins, are suspected to affect the activity of matrix metalloproteinase [5], for example, differently in different aortic regions [18]. The vascular smooth muscle cells forming the tunics of the aortic root, originate from the secondary heart field—a derivate of the lateral plate mesoderm. The cells of the ascending aorta and aortic arch originate from the neural crest, and the descending portion is built by paraxial mesoderm (so-called "somatic mesoderm") [16–18]. These embryologic differences likely effect not only the development of aneurysms, but also the long-term adult behavior. Furthermore, the "seams" between the different originating regions are hypothesized to be the vulnerable locations of the aorta and predisposing areas of aortic dissection [16].

Clinical Implications

Guidelines, published as a consensus paper of multiple associations, recommend replacing the aortic root in nonsyndromic patients at 55 mm or at a dilation of 5 mm or more per year [6–8]. Given the growth rate in the present study, the aortic root, found with an initial diameter of 37.4 mm (in patients aged 62 years on average), would not meet the 50 mm threshold for more than an immense 29 years. Only patients with a diameter of 45 mm and above are found to be at any substantial risk of a contemporary growth up to critical root dilation (at approximately 10 years after initial surgery). Our institutional policy regarding root replacement—in consent with many high-volume and specialized academic centers—anticipates intervention at lower thresholds than guidelines state, and recommends surgery at 45 mm.

These findings attest strongly to the safety of root-sparing aortic replacement in case of nonaneurysmal roots. The root-sparing technique, used in all patients of

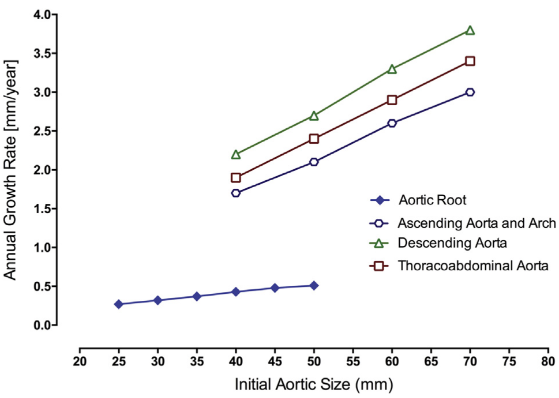

Fig 1. Annual growth rates according to different portions of the aorta: aortic root (bright blue line); ascending aorta and arch (dark blue line); descending aorta (green line); and thoracoabdominal aorta (brown line). (Data on the ascending aorta and arch, descending aorta, and thoracoabdominal aorta were evaluated and taken from a recent publication of our group [15]).

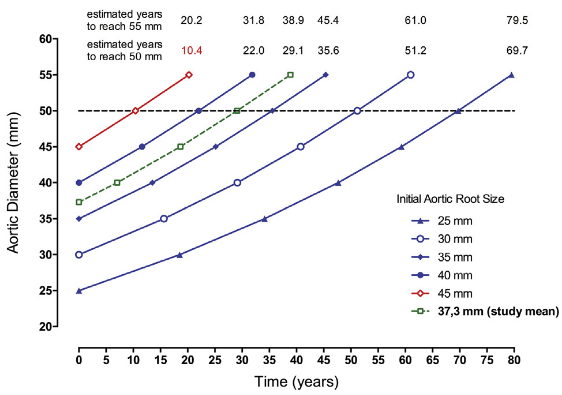

Fig 2. Aortic diameter according to initial aortic root size and growth rate: 25 mm (triangles); 30 mm (open circles); 35 mm (solid diamonds); 40 mm (solid circles); and 45 mm (open diamonds). Study mean was 37 mm (open squares). Horizontal dashed line represents the 50 mm diameter threshold.

Table 3. Results of Regression Models

Eq.	Variable	Adj. R^2	F	Coefficient		T Statistic	*p* Value
				Mean	95% CI		
4.1	TIME	0.38	122.77	0.00065	0.00053–0.00077	11.08	<0.0001
4.2	TIME	0.38	61.10	0.00067	0.00046–0.00088	6.28	<0.0001
	AVR			−0.000023	…	0.18	0.857
4.3	TIME	0.38	61.27	0.00063	0.00048–0.00078	8.21	<0.0001
	BICUSPID			0.000059	−0.00018–0.00030	0.49	0.622

Interaction terms between growth rate, time (TIME), and both aortic valve replacement (AVR) and bicuspid valve morphology (BICUSPID). The equation numbers refer to the numbering in the Methods section.

Adj. = adjusted; CI = confidence interval; Eq. = equation.

the present cohort, replaces the ascending aorta superior to the level of the aortic valve suspension (sinotubular junction), and consequently, the coronary arteries (alternative terms: supracoronary or supracommissural), and leaves the native root tissue in situ. Sparing the root is the technically more simple approach compared with root replacement procedures (composite replacements, valve-sparing, remodeling, and so forth) because of lack of coronary artery reimplantation, and results in excellent clinical outcomes [9, 19–22]. Leaving the root behind in ascending aortic replacements, both De Paulis and colleagues [23] and Park and associates [24] noted that neither a progressive dilation of nonreplaced sinuses nor an incidence of root reoperations is evident in aneurysm patients, in contrast to aortic dissection. Their findings support the thrust of the current paper.

Dilation of the native root over time, however, is just one component of the complex decision whether to address the aortic root. Pathology and phenotype of the aortic aneurysm, underlying aortic valve pathology and its functional correlates, and the operative risk of primary aortic root replacement or of a potential reoperation at the aortic root need to be taken into account and individually weighed. In a separate upcoming publication, we report long-term outcomes of more than 600 aortic root replacements done contemporaneously with the patients reported in this study; our results, like those at other experienced centers, confirm the low risk of aortic replacement at high-volume institutions [10]. Therefore, the root-sparing procedures in our current report were accumulated because we believed they were appropriate for the patients and their anatomy—not out of any concern that full aortic root replacement was too dangerous.

A concomitant replacement of the aortic valve showed no significant impact on the growth rate of the aortic root. Any hypothesized effect of a proximal affixation by the prosthetic scaffold, either positively as root stabilization or negatively as decreased stretching capability, could not be confirmed.

Impacting Factors

The morphology of the aortic valve, which shares the neural crest as embryonic heritage with the ascending aorta [25], appeared not to affect the growth rate in the present study. Della Corte and colleagues [26] reported in bicuspid (but nonoperative) patients a growth rate of 0.3 mm per year, comparable to the 0.42 mm per year in our study. They also found a correlation between root phenotype of the aorta and valve morphotype with right-left fusion. In total, 41% in their cohort had an increase of the root diameter over time.

The most important impact on root dilation is exerted by the Marfan syndrome. Based on a mutation in the *FBN1* gene encoding *fibrillin-1* [27], Marfan patients had progressive dilation of the root (approximately 60% to 84% of all patients [28]) with the risk of dissection, rupture, and valve regurgitation. The growth rate in this connective tissue disorder was estimated to be approximately 1.5 mm per year by Lazarevic and colleagues [29] in 2006, and therefore was 3.5-fold higher than in the present nonsyndomic cohort. Although Meijboom and colleagues [30] calculated only a rate of 0.42 mm per year for males and 0.38 mm per year for females, 1 in 7 men and 1 in 9 women showed a fast growing root of more than 1.5 mm per year, resulting in a significant increase of aortic dissection in those patients (both studies examined nonsurgical patients). Therefore, an aortic replacement in root-sparing technique is not recommended for patients with syndromic diseases.

Study Limitations

The study is retrospectively based on a relatively small number of patients with an imaging interval between first and most recent image of approximately 3.5 years, which potentially raises concerns about selection bias and generalizability. Advanced analysis focusing on the influence of age, sex, valve pathology, and comorbidities were denied statistically owing to small subgroup sizes.

Thin slices (5 to 10 mm), orthonormal projection, and electrocardiography-gated imaging were preferred, but not available in all cases (especially for patients operated on in the earlier years of this study). We made every effort to evaluate the size in a plane perpendicular to the blood flow (avoiding obliquity); we made full use of all images available, including axial, coronal, and sagittal. Furthermore, follow-up scans were measured in the very same projection and modality used for the baseline measurements; therefore, technical issues should not significantly influence the change in size.

As noted, 9 patients were excluded because of incomplete follow-up, which was defined as inadequate quality of the images (for example, distorted projection, lack of contrast [CT], solely axial images [CT], or no available reconstruction [CT]), incomparable projection between S_B and S_L, or, if raw images were not available, lack of precise aortic root measurement. Two patients were classified as outliers by measurements greater than two standard deviations from the mean, and excluded based on the recommendation of our collaborative statistician. Even if they would be included into the study, however, the results are little affected.

Conclusions

The aortic root grows significantly more slowly than the remaining portions of the aorta. Neither a concomitant AVR nor the valve morphology appears to impact its growth rate. Seen in conjunction with clinical results, the replacement of the aorta by a root-sparing technique is an appropriate and safe approach, even in the long run, for patients with a root diameter less than 45 mm. Decision making with regard to aortic root procedures requires a multidimensional view, however; knowing the efficacy of a root-sparing approach is one important step in this process.

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5.3 V-shape noncoronary sinus remodeling in ascending aortic aneurysm and aortic root ectasia.

V-shape noncoronary sinus remodeling in ascending aortic aneurysm and aortic root ectasia

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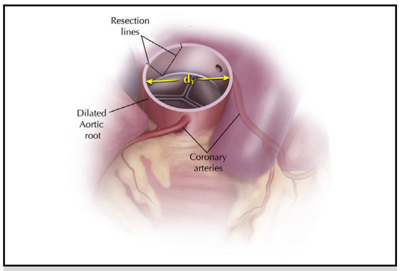
ABSTRACT

Objective: The study objective was to describe our initial experience performing a V-shaped single sinus remodeling procedure in patients with ascending aortic aneurysm and moderate aortic root ectasia.

Methods: Twelve consecutive patients underwent supracoronary ascending aortic replacement with V-shaped noncoronary sinus remodeling (median age, 63 years [range, 56-77]; 10 patients [83%] were male). All patients had an ascending aortic aneurysm (median diameter 48 mm [range, 42-53]) and aortic root ectasia (median root diameter, 43 mm [range, 38-49.7 mm]). A deep V-shaped (triangular) portion of the noncoronary sinus was excised, and the wall was directly reapproximated in 2 layers, 1 everting mattress suture layer followed by a running over-and-over layer.

Results: No technical complication due to root remodeling was observed. All patients survived the initial hospitalization. Only 1 patient required reexploration for bleeding, unrelated to the V-shaped repair. On postoperative computed tomography, every patient showed reduction in maximal aortic root diameter and cross-sectional area. Mean aortic root diameter was reduced from 4.30 cm (range, 3.82-4.97) to 3.81 cm (range, 3.58-3.96) ($P < .0006$). Mean aortic root cross-sectional area was reduced from 1452 mm^2 (range, 1327-1615) to 1180 mm^2 (range, 961-1328) ($P < .0002$). Mean wall tension decreased postoperatively by 12%.

Conclusions: The V-shaped resection of the noncoronary sinus is a viable option for patients with moderate aortic root enlargement. This technique reduces aortic root diameter, cross-sectional area, and wall tension. We offer this technique as another option in the surgeon's armamentarium. (J Thorac Cardiovasc Surg 2017;154:72-6)



V-shaped noncoronary sinus resection procedure for remodeling of aortic root.

Central Message

The V-shaped resection of the noncoronary sinus is a viable option for patients with moderate aortic root enlargement.

Perspective

V-shaped resection of the noncoronary sinus is a simple, quick, reliable supplement to ascending aortic replacement for patients with moderate aortic root enlargement. This technique reduces aortic root diameter, cross-sectional area, and wall tension. This approach is useful in elderly patients and those requiring extensive surgery for primary pathologies outside the aortic root.

See Editorial Commentary page 77.

The aortic valve cusps, the annulus, and the sinuses of Valsalva work as 1 functional unit. Restoring or remodeling such a unit adequately is beneficial for functional long-term prognosis.[1] Ascending aortic aneurysms often include the sinotubular junction (STJ) and extend into the root portion of the aorta, but most commonly affect the noncoronary or right coronary sinus.[2] Such pathologies (ascending aneurysm with root ectasia) often result in aortic insufficiency. Full aortic root replacement will eradicate all the pathology of the valve, root, and ascending aorta. However, this may represent excessive surgical intervention for an elderly or infirm patient. Valve-sparing aortic root replacement is another option (often accompanied by valve repair);

Scanning this QR code will take you to a video for the article.

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Abbreviation and Acronym
STJ = sinotubular junction

however, the same proviso applies regarding the magnitude of operation for the old or infirm. Urbanski and colleagues[3] has described a more limited approach, with resection of 1 or more sinuses, which are replaced by a shield-shaped patch.

We have accumulated initial experience with a simpler and more expedient option, especially suited to elderly patients, in whom extensive aortic root surgery for sinus ectasia may not be warranted. These are patients generally undergoing operation primarily for ascending aneurysm (body of the ascending aorta), with only mild to moderate enlargement of the aortic root, in the range of 4 to 5 cm. For younger patients and for those with severe root enlargement greater than 5 cm, we use full aortic root replacement. We occasionally apply the V-shaped aortic root remodeling in somewhat younger patients who require extensive additional surgery (eg, additional full aortic arch replacement).

This article describes our initial experience performing a straightforward V-shaped singular sinus remodeling procedure in patients with ascending aortic aneurysm and moderate aortic root ectasia. The V-shaped resection is performed in the noncoronary sinus, the most commonly affected among the 3 sinuses. We largely confine application of this technique to cases in which the aortic valve is simultaneously replaced, usually by a biological prosthesis in this age group. We hesitate to perform this procedure without concomitant aortic valve replacement, because sinus anatomy is changed and aortic insufficiency may be induced, although we did perform this occasionally with preservation of the native valve. Induction of aortic insufficiency is not an issue with concomitant aortic valve replacement. Of course, concomitant aortic valve replacement is a common requirement in the elderly age group because of degeneration or calcification of the valve leaflets.

MATERIALS AND METHODS

Surgical Technique

The patient is prepped and draped in a standard fashion, and a median sternotomy is performed. Cannulation sites are chosen according to the surgeon's preference. After initiating cardiac arrest, the aorta is circularly opened just above the STJ, and, if applicable, the aortic valve is replaced. For remodeling the root, a deep V-shaped or triangular portion of the noncoronary sinus is excised and the wall is directly reapproximated in 2 layers, 1 everting mattress suture layer (4-0 pledgeted Ethibond; Ethicon, Somerville, NJ) and then a running over-and-over layer (4-0 Prolene). The edges of the remnant portions of the noncoronary sinus come together easily, without tension, even after a wide resection.

The proximal anastomosis of the ascending aortic replacement is performed to the smaller cuff (equal to the new STJ) of the aortic root by running suture. We often add a dab of BioGlue (CryoLife, Kennesaw, Ga) at the site where the V-shaped resection comes together with the proximal anastomosis of the main ascending aortic graft, for added security. We routinely reinforce the posterior wall of nearly all aortic anastomoses with multiple interrupted sutures (4-0 Ethibond; Ethicon) for added security. After performing the distal aortic anastomosis, the patient is weaned from cardiopulmonary bypass, and the procedure is completed in the usual fashion (See Figure 1 and Video 1).

RESULTS

Patient Population and Operative Data

Between March 2013 and May 2016, 12 consecutive patients underwent supracoronary ascending aortic replacement with V-shaped noncoronary sinus remodeling. Their median age was 63 years (range, 56-77), body mass

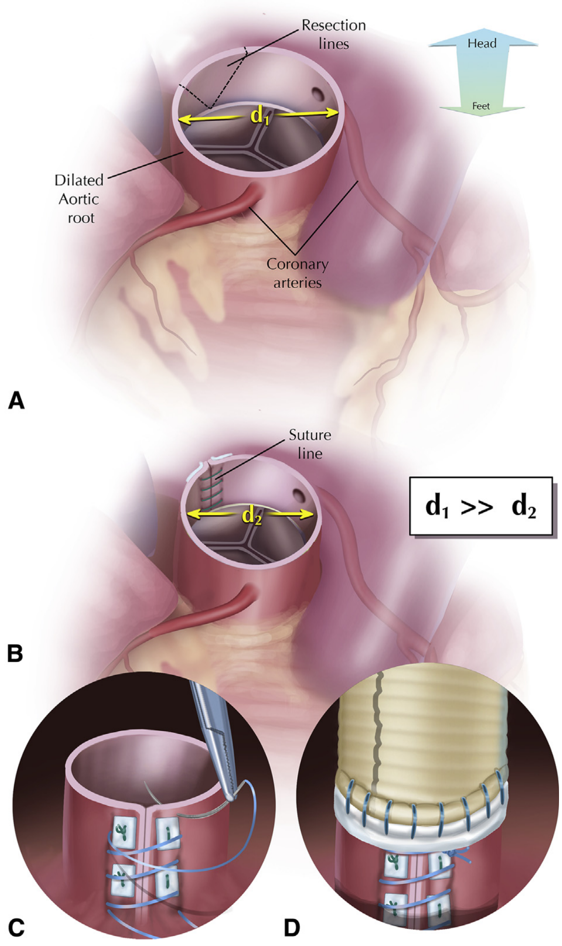
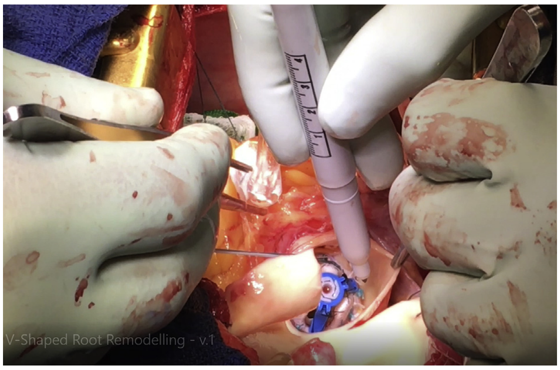


FIGURE 1. Artist's rendition of V-shaped noncoronary sinus resection procedure for remodeling of aortic root. A, Line of resection indicated. B, Reapproximation after resection. C, Details of first everting layer of pledgeted sutures and second running layer. D, End-to-end attachment of ascending graft to remodeled aortic root.



VIDEO 1. A video illustration of the V-shaped noncoronary sinus resection procedure for aortic root remodeling. Video available at: http://www.jtcvsonline.org/article/S0022-5223(16)31685-3/addons.

index was 28.2 (21.9-39.1), and 10 (83%) were male. All patients had ascending aortic aneurysms (median diameter of 48 mm [range, 42-53] and aortic root ectasia [sizes given later]). The aortic valve was severely diseased in 9 patients (75%; 2 via stenosis, 7 via insufficiency) and showed mild regurgitation in 3 patients (25%). Bicuspid morphology was found in 3 patients (25%). Comorbidities included coronary artery disease in 2 patients (17%), chronic obstructive pulmonary disease in 4 patients (33%), and arterial hypertension and dyslipidemia in 8 patients each (67%). Left ventricular ejection fraction was 64% (range, 40-70), and creatinine level was 0.85 (range, 0.7-1.0).

All patients underwent supracoronary ascending aortic replacement, 4 patients (33%) underwent hemiarch replacement, and 2 patients (17%) underwent total arch replacement. The aortic valve was replaced in 10 patients (83%) and spared in 2 patients (17%, both with only preoperative mild valve insufficiency and central jet). Concomitant coronary artery bypass grafting was required in 1 patient (8.3%).

Cardiopulmonary bypass and crossclamp times were 153.5 minutes (range, 131-202) and 107.5 minutes (69-136), respectively. Hypothermic circulatory arrest was required in 6 patients (50%; 28 minutes; 19.5°C).

Operative Outcome

No technical complication due to root remodeling was observed, and the aortic valve achieved full competency when preserved (n = 2). One patient (8.3%) experienced bleeding requiring reexploration (distal aortic site), and 5 patients (42%) developed postoperative atrial fibrillation. Otherwise, no other postoperative morbidities were found. Median length of stay in the intensive care unit and in hospital were 4 days (range, 2-5) and 6 days (range, 5-8), respectively. Step-down beds were difficult to obtain during this period of time, and patients often stayed in the intensive care unit for lack of beds for the majority of their hospital stay.

Remodeling Outcome

Preoperative and postoperative aortic root diameters and cross-sectional areas were compared by an independent radiologist unfamiliar with the patients. These are listed in Table 1. Corresponding contrast computed tomography scans of good quality were available for 10 of the 12 patients. Every patient showed reduction in maximal aortic root diameter and cross-sectional area. Mean aortic root diameter was reduced from 4.30 cm (range, 3.82-4.97) to 3.81 cm (range, 3.58-3.96) ($P < .0006$). Mean aortic root cross-sectional area was reduced from 1452 mm^2 (range, 1327-1615) to 1180 mm^2 (range, 961-1328) ($P < .0002$). The simplified formula for Laplace's law $T = P \times D$ shows that mean wall tension (Table 2) decreased by 12%. We used the percent change in diameter to represent the change in wall tension, because tension is proportional to diameter.

DISCUSSION

The presented surgical technique represents a technically simple and effective option to address moderate sinus dilatation by remodeling the noncoronary sinus. This technique accomplishes significant reduction in transverse diameter and cross-sectional area of the aortic root, with attendant reduction in tension in the aortic wall.

In this initial experience, the V-shaped remodeling was accomplished safely. Only 1 patient required reexploration for bleeding, unrelated to the V-shaped repair.

We believe that this V-shaped technique is appropriate for elderly patients with moderate dilatation of the aortic root segment who require aortic valve replacement for stenosis

TABLE 1. Dimensional parameters, comparing preoperative and postoperative computed tomography scans

	Preoperative		Postoperative	
Patient no.	Root diameter (cm)	Root area (mm^2)	Root diameter (cm)	Root area (mm^2)
1	4.71	1597	3.96	1094
2	4.37	1521	3.96	1328
3	4.35	1521	3.90	1260
4	4.16	1529	3.96	1381
5	3.82	1229	3.75	961
6	4.97	1505	3.47	1017
7	4.57	1615	3.93	1271
8	4.30	1452	3.94	1228
9	4.02	1327	NA	NA
10	4.16	1405	3.58	1182
11	NA	NA	NA	NA
12	3.92	1272	3.61	1081
Mean	4.30*	1452†	3.81*	1180†

NA, Not available (because of noncontrast scan). *$P < .0006$. †$P < .0002$.

TABLE 2. Reduction in wall tension

Patient no.	Reduction in aortic wall tension (%)
1	16
2	10
3	11
4	5
5	2
6	31
7	14
8	9
9	NA
10	14
11	NA
12	8
Mean	12%

NA, Not available.

or insufficiency. It also may be considered as a simple option for addressing moderate dilatation of the aortic root in patients requiring extensive surgery for other segments of the aorta or for other concomitant cardiac issues (eg, aortic arch replacement, coronary artery bypass, mitral valve surgery). Of note, we do not recommend this technique for patients with Marfan's disease or other connective tissue syndromes, because the tissue weakness is too severe for any procedure short of full aortic root replacement. However, such patients usually would present with maximal dilatation at the root segment, so the root would de facto be the primary focus of surgery.

Westaby and colleagues[2] and Urbanski and colleagues[3] have taken an approach of resecting the noncoronary sinus (and other sinuses, when needed). However, both Westaby and colleagues and Urbanski and colleagues use a shield-shaped patch or graft extension to replace the resected noncoronary sinus. Our technique differs in that we approximate the tissues primarily after V-shaped excision, thus accomplishing a reduction in the diameter of the aortic root and reducing the wall stress in that area. Our technique also is suitable for individuals with extensive calcification of the aortic wall around the coronary ostia or severe calcification of the proximal right or left coronary arteries; root replacement may be especially hazardous in such circumstances.

Westaby and colleagues[2] and Urbanski and colleagues[3] also noted that the noncoronary sinus is the most commonly and earliest affected by dilatation. This observation is consistent with the concept that branch vessels provide support and reinforcement to the arterial wall. It has been shown[4,5] that excess collagen fibers reinforce areas of arterial bifurcation, like biological "rebar." Reinforcement from collagen surrounding the right and left coronary arteries may underlie the relative protection of the corresponding sinuses from dilatation.

V-shaped resection has the potential to distort the noncoronary sinus, resulting in prolapse of the noncoronary leaflet and aortic insufficiency. For this reason, we prefer to apply the V-shaped resection when the aortic valve is being replaced, in which case the biological or mechanical prosthetic valve is immune to such distortion. When preserving the valve, the technique of Ugur and colleagues[6] is preferable; this technique replaces the dilated noncoronary sinus with a tongue-like extension of the main aortic graft, which is sutured into the bed of the resected noncoronary sinus.

We do not recommend the V-shaped technique for aortas greater than 5 cm in diameter, for which we recommend a formal root replacement type procedure. It is possible that our patients may have done well without the V-shaped resection, but we are wary of leaving behind an aortic dimension greater than 4 cm, for fear of the potential for late dilatory consequences. In the current era of 3-dimensional aortic printing from computed tomography scans, examining printed models may facilitate and enhance resection strategy for the noncoronary sinus.

Why not perform a full aortic root replacement in everyone? We believe strongly in aortic root replacement for severe root pathology. The senior author has personally performed more than 500 aortic root replacements.[7] However, we believe that full root replacement may be more than needed when the major aortic pathology is located elsewhere and, especially, when the patient is elderly or the operation is extremely extensive because of multiple pathologies outside of the aortic root zone. Also, replacing the coronary buttons onto a graft adds a small but important additional risk. In contrast to supracoronary ascending replacement, which does not increase surgical risk when performed concomitantly,[8] aortic root replacement carries additional technical complexity and, thus, increases the operative risk slightly.[7,9]

In a recent study,[10] we examined the annual growth rate in an untouched aortic root after supracoronary aortic replacement. We found slow growth of the nonresected root (0.41 mm/y) and no instance of dissection in the nonresected root segment. The projected time to reaching a diameter for surgical resection (nominally 5.5 cm) was more than 25 years. In the case of V-shaped noncoronary resection, the root is made substantially smaller, so even more indolent behavior of the root can be expected than in our recent study of root sparing without V-shaped resection. Furthermore, it is likely that extensive scarring around the V-shaped resection site will discourage dilatation or free rupture.

Study Limitations

We have reported a favorable but limited experience with the technique of V-shaped resection of the noncoronary sinus. More experience and a longer follow-up are required to determine the appropriate potential role of this technique in the surgeon's armamentarium.

CONCLUSIONS

We report our initial experience with a simple, quick, reliable V-shaped resection of the noncoronary sinus as a supplement to ascending aortic replacement and aortic valve replacement for patients with moderate aortic root enlargement. This technique reduces aortic root diameter, cross-sectional area, and wall tension. We have found this approach useful in elderly patients and those requiring extensive surgery for primary pathologies outside the aortic root. We believe that this V-shaped resection technique offers another alternative surgical technique for the moderately dilated aortic root, between the full aortic root replacement (which may be more than needed) and leaving the root alone entirely (which may be less than needed). We offer this technique as another option in the surgeon's armamentarium.

Conflict of Interest Statement

Authors have nothing to disclose with regard to commercial support.

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Key Words: aortic aneurysm, aortic root remodeling, aortic root sparing, sinus of Valsalva

5.4 Sparing the aortic root in acute aortic dissection type A: Risk reduction and restored integrity of the untouched root.

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Sparing the aortic root in acute aortic dissection type A: risk reduction and restored integrity of the untouched root[†]

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Abstract

OBJECTIVES: The purpose of the study was to evaluate the operative outcome and the risk of retained proximal aortic tissue following the root-sparing (RS) technique in acute aortic dissection type A (AADA).

METHODS: Between 2002 and 2014, 338 patients underwent repair of AADA; 74% of those were performed with the RS technique and 26% with root replacement (RR). The mean age was 62.4 ± 13.4 years (69% male) in the RS group and 56.1 ± 13.1 years (76% male) in the RR group ($P < 0.001$). Aortic insufficiency 2+ or higher was present in 35% (RS) and 72% (RR, $P < 0.001$), and bicuspid morphology in 1% (RS) and 16% (RR, $P < 0.001$).

RESULTS: Cardiopulmonary bypass time and cross-clamp time were significantly lower in the RS group (199 ± 71 vs 274 ± 110 min; 108 ± 46 vs 169 ± 55 min; $P < 0.001$ each), while no difference was seen with regard to distal operative extent, the use of circulatory arrest and adjunct protection strategies. The postoperative incidence of bleeding (18 vs 34%; $P = 0.003$), low cardiac output (14 vs 29%; $P = 0.002$) and sepsis/systemic inflammatory response syndrome (5 vs 12%; $P = 0.037$) were higher after RR, whereas mortality and survival did not differ between the groups. The aortic root grows at 0.40 ± 0.13 mm/year after AADA and thus, the need for potential reoperation was estimated at greater than 40 years. Freedom from root events after 5 and 10 years of follow-up was 97 and 92% in the RS group, and 100% each in RR group, respectively.

CONCLUSIONS: Both RS and RR procedures can be performed with an acceptable postoperative outcome and late survival in AADA. The RS approach can safely be performed with excellent results in acute survival and stabilizes the native root for a long period of time.

Keywords: Aortic root • Natural history • Aortic dissection • Supracoronary ascending replacement • Root replacement • Aortic events

INTRODUCTION

The outcome of surgical management of acute aortic dissection type A (AADA) has improved over recent decades due to advances in surgical technique and equipment [1]. These improvements and technical developments (e.g. haemostatic impregnated grafts and frozen elephant trunk prostheses), however, also opened a debate regarding the optimal balance between treating the urgent necessities at that time and preventing potential late future complications [2–4].

In this context, the optimal operative strategy regarding the proximal aorta remains controversial [5]. Replacing the entire aortic root (i.e. composite graft replacement and Bentall procedure) appears as prognostically the safest pathway, but adds technical complexity and is potentially problematic due to the need for mobilization and connection of the acutely dissected coronary artery buttons [6]. A more conservative repair, by resecting the ascending aorta in a supracoronary fashion [root-sparing (RS) technique], represents the surgically easier approach with less postoperative morbidity and mortality [7, 8], but leaves the native root untouched and potentially problematic in the future.

In non-dissected aneurysmal patients (non-syndromic), the annual growth rate of a spared root is ∼0.4–0.5 mm; consequently, the need for a secondary root replacement (RR) after an initial RS procedure is rather unlikely [9]. But, does this benefit also

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apply equally in terms of AADA, or do we necessitate (with the surgically easier approach) a higher incidence of reoperations during follow-up [3]? And, does an untouched root increase the secondary mortality due to the risk of rupture and/or repetitive dissection in that area during long-term follow-up?

The aim of this study was to evaluate the effectiveness of RS procedures and the integrity of the untouched root in AADA.

MATERIALS AND METHODS

Study design

All consecutive patients admitted with the diagnosis of acute type A aortic dissection at Yale-New Haven Hospital (USA) and the Medical University of Innsbruck (Austria) between 2002 and 2014 were retrospectively analysed by chart and image review. Patients with syndromic connective tissue disorders (Marfan, Ehlers–Danlos and Loeys–Dietz syndromes) and patients who were declined surgical intervention (e.g. due to age, comorbidities and malperfusion syndrome) were excluded. The cohort was divided into two groups according to the surgical approach of the proximal aorta. The RS group included all patients who received an ascending aortic replacement above the commissures (supracoronary and supracommissural), whereas the RR group consisted of patients undergoing replacement of the aortic root with reimplantation of the coronary arteries (including conduit replacements, classical Bentall and David procedures). Patients with aortic root repair by suture or glue ($n = 17$), and replacement of solely the non-coronary sinus ($n = 33$), were excluded due to unclear assignment to one of the groups.

Demographic characteristics, operative data and in-hospital postoperative outcomes were comparatively analysed. Root events including proximal aortic rupture, recurrent dissection of the residual native root tissue, progressive root aneurysm (>55 mm inner diameter) and secondary RR during follow-up were collected and freedom from root events was calculated. Survival was determined from the Social Security Death Index (US), Civil Registry Office (AUT) and chart review, and analysed using the Kaplan–Meier estimation. The Human Investigation Committee of Yale University and the University of Innsbruck approved this retrospective study.

Patient population and selection of surgical technique

Between 2002 and 2014, 342 consecutive non-syndromic patients admitted with an acute type A aortic dissection were intended for surgical intervention. Among those, 4 patients (mean age 74.3 ± 8.1 years) died before implementing cardiopulmonary bypass (CPB), due to rupture during transportation, anaesthesia induction or sternotomy. Thus, 338 patients were included in the study. Two hundred and forty-nine (74%) received an ascending replacement via the RS technique (RS group) and 89 (26%) underwent the RR technique (RR group). The mean age was 62.4 ± 13.4 years in the RS and 56.1 ± 13.1 years in the RR group ($P < 0.001$), and male gender predominated in both groups [165 (66%) vs 68 (76%); $P = 0.084$]. The dissection extended to the descending aorta and below in 213 (86%) patients in the RS and 73 (83%) patients in the RR group ($P = 0.494$). Patients' demographic characteristics and comorbidities are depicted in detail in Table 1.

Table 1: Demographic characteristics and comorbidities

	Total population (*n* = 338)	Root sparing (*n* = 249)	Root replacement (*n* = 89)	*P*-value
Age (years)	60.7 ± 13.5	62.4 ± 13.4	56.1 ± 13.1	**<0.001**
Male gender	233 (69%)	165 (66%)	68 (76%)	0.084
BMI (kg/m^2)	27.5 ± 5.2	27.6 ± 5.4	27.1 ± 4.8	0.499
Extension				
Limited to ascending portion	52 (15%)	36 (15%)	16 (17%)	0.494
Involving descending aorta	286 (85%)	213 (86%)	73 (83%)	0.494
Supra-aortic extension	212 (63%)	153 (62%)	59 (66%)	0.523
Aortic valve				
Insufficiency II° plus	148/332 (45%)	87 (35%)	61 (72%)	**<0.001**
Bicuspid morphology	17/337 (5%)	3 (1%)	14 (16%)	**<0.001**
Clinical presentation				
Tamponade	68 (20%)	50 (20%)	18 (20%)	1.000
Pericardial effusion	162 (48%)	126 (51%)	36 (40%)	0.109
Neurological abnormality	50/324 (15%)	39 (16%)	11 (13%)	0.492
Malperfusion	58/315 (18%)	41 (18%)	17 (21%)	0.513
Resuscitation	25 (7%)	14 (6%)	11 (12%)	0.056
Comorbidities				
Bovine arch	54 (16%)	45 (18%)	9 (10%)	0.092
Coronary artery disease	54/315 (17%)	47 (20%)	7 (9%)	**0.036**
COPD	31/315 (10%)	26 (11%)	5 (6%)	0.281
Renal insufficiency	38/315 (12%)	27 (11%)	11 (14%)	0.549
Creatinine (mg/dl)	1.20 ± 0.78	1.19 ± 0.84	1.26 ± 0.57	0.399
Hypertension	255/315 (81%)	199 (84%)	56 (72%)	**0.021**
PAD	22/316 (7%)	18 (8%)	4 (5%)	0.611
Hx of neurological abnormality	10/315 (3%)	8 (3%)	2 (3%)	1.000

Data are shown as mean ± standard deviation, number (percentage) or as [reported]. CAD was evaluated either by patients' medical history or, recently, by CT angiogram. Statistical significant level was defined at $P \leq 0.05$ (bold values).
BMI: body mass index; COPD: chronic obstructive pulmonary disease; Hx: history; PAD: peripheral arterial disease.

The selection of surgical technique and extent is recommended by the institutional policies as follows: a RR is indicated by a severely dissected left- or right-coronary sinus or at a root diameter of 45 mm and above. In younger patients, patients with bicuspid valve morphology or a diseased valve (each characteristic significantly different between the groups; Table 1), and in patients with Marfan's syndrome (excluded from this study), the root was replaced at lower diameters according to the individual decision by the surgeon.

Aortic root diameter and growth rate

Aortic root diameter in the RS group was evaluated via CT scan images, echocardiographic images or corresponding reports (in a descending order for preference) and measuring the inner diameter. For each patient, the postoperative baseline diameter (first available diameter after surgery) and the last follow-up diameter were taken. The growth rate of the aortic root was estimated according to Rizzo *et al.* [10] and, in a second step, compared with the rate of growth in aneurysmal (non-dissection) patients from a very recent study performed by the Aortic Institute [9].

The key variables in this analysis are *FIRST SIZE* (S_F), classified as the first evaluated root diameter after surgery, *LAST SIZE* (S_L), classified as the last available root diameter during follow-up, and *TIME* (T), classified as the Δ time between both images. The equation defining aortic growth is written as

$$S_L = S_F \exp^{(\alpha * T + \beta * StudyGroup * T)}, \quad (1)$$

where exp denotes the exponential function, *StudyGroup* represents a binary variable (equal 1 for dissection patients and equal 0 for aneurysmal patients), α and β are coefficients to be estimated, and other terms are as defined above.

For estimation purposes, we took a natural logarithm of both sides and rearranged the terms, yielding

$$\ln \frac{S_L}{S_F} = \alpha * T + \beta * StudyGroup * \mathrm{T}. \quad (2)$$

The S_L/S_F was calculated for all patients and values ±2 SD from the mean deleted to eliminate outliers.

Statistical analysis

Data are presented either as frequency distribution and percentages for categorical variables, or as mean ± standard deviation for continuous variables. The Pearson's χ^2 test or Fischer's exact test was used for analysing categorical variables, and the Student's *t*-test or Mann–Whitney U-test was used for continuous variables. Survival was estimated by using Kaplan–Meier analysis, and the log-rank test was used to compare survival between the groups. Statistical analysis was performed using IBM® SPSS® Statistics version 23.0 (IBM®, Inc., Armonk, NY, USA) in collaboration with the Departments of Economics and Preventive Medicine of Stony Brook University (Stony Brook, NY, USA).

RESULTS

Operative data and intraoperative mortality

The aortic root was replaced using the valve-sparing technique (David V procedure) in 12 (14%) and using a conduit graft in 77 (87%) patients. Five (7%) of the RRs were done with a concomitant modified Cabrol procedure due to technical difficulties involved in the coronary artery buttons [11]. In the RS group, 22 patients (9%) underwent aortic valve replacement, via either the intra-annular or supra-annular technique, and 37 (15%) received a suture valve resuspension (if the valve showed a regurgitation of 2 + or higher, but without structural deterioration), according to the surgeon's preferred technique. Two hundred and forty-two (97%) underwent circulatory arrest in the RS group versus 86 (97%) in the RR group ($P = 0.727$), without any difference between the groups regarding cerebral and organ protection strategy. Total CPB (prolonged by 75 min on average in the RR group) and cross-clamp time (prolonged by 61 min on average in the RR group) differed significantly between the groups ($P < 0.001$). Arterial cannulation site was distributed equally among the groups. Further operative details are given in Table 2.

Eleven (3%) patients died intraoperatively, 7 of those after RS ascending replacement and 4 after RR ($P = 0.489$). Causes of intraoperative death were rupture (RS: 1; RR: 0), bleeding (RS: 2; RR: 2) and low cardiac output (RS: 4; RR: 2).

Early postoperative outcome and late survival

The postoperative morbidities differed significantly with regard to bleeding requiring re-exploration [42 (18%) in RS vs 29 (34%) in RR; $P = 0.003$], low cardiac output [32 (14%) in RS vs 25 (29%) in RR; $P = 0.002$] and sepsis/systemic inflammatory response syndrome [11 (5%) in RS vs 10 (12%) in RR; $P = 0.037$]. Intensive care unit and in-hospital stay were prolonged in the RR group by 2.1 ($P = 0.198$) and 5.1 days ($P = 0.048$), respectively. Operative mortality showed no statistically significant better outcome in the RS group [38 (15%) vs 18 (20%) in the RR group ($P = 0.319$)]. Further postoperative information and mortality data are listed in detail in Table 3. Kaplan–Meier estimation (Fig. 1) showed no difference between late survivals of both the groups ($P = 0.840$).

Aortic root diameter and growth rate

In total, 105 (42%) patients undergoing ascending replacement via the RS technique had adequate postoperative measurements of the root portion. Among those, 8% showed a baseline diameter between 45 and 50 mm and 4% larger than 50 mm. The mean baseline diameter of the root (S_F) was 37.8 ± 4.9 mm (range 24.2–51.4) and the mean last diameter (S_L) was 39.4 ± 5.0 mm (range 26.8–56.3), taken an average of 39.1 ± 31.4 months after the baseline imaging. Hence, following the methodology described above, the root did grow over time (coefficient for *TIME*: 0.0009374; $P < 0.001$) and the rate equated to 0.40 ± 0.13 mm/year (mean). Furthermore, associated growth rates were higher with larger baseline diameter, as depicted in Fig. 2. Compared with the exclusively aneurysmal (non-dissected) diseased aortas [9], the non-resected root of dissection patients showed no significant different rate of dilatation (coefficient for *TIME* and *StudyGroup*: −0.0002249; $P = 0.064$).

Aortic root events

Seven (3%) patients suffered from root events after initial sparing of the native root during aortic replacement (none in the RR

Table 2: Operative data

	Total population (*n* = 338)	Root sparing (*n* = 249)	Root replacement (*n* = 89)	*P*-value
Prior cardiac procedure	21 (6%)	15 (6%)	6 (7%)	0.801
Cardiopulmonary bypass				
Time (min)	219 ± 89	199 ± 71	274 ± 110	**<0.001**
Cross-clamp time (min)	124 ± 56	108 ± 46	169 ± 55	**<0.001**
Circulatory arrest	328 (97%)	242 (97%)	86 (97%)	0.727
Time (min)	39 ± 18	40 ± 19	39 ± 16	0.777
Lowest temperature (°C)	20 ± 3	19 ± 3	20 ± 3	0.085
DHCA alone	130/335 (39%)	104 (42%)	26 (29%)	**0.032**
w/RCP	52/335 (16%)	39 (16%)	13 (15%)	0.865
w/SACP	144/335 (43%)	97 (39%)	47 (53%)	**0.034**
Arterial cannulation site				
Aorta	19 (6%)	16 (6%)	3 (3%)	0.422
Axillary	120 (36%)	90 (36%)	30 (34%)	0.796
Femoral	199 (59%)	143 (57%)	56 (63%)	0.451
Proximal aorta				
Aortic valve replacement	99 (29%)	22 (9%)	77 (87%)	-
Valve resuspension	37 (11%)	37 (15%)	-	-
David procedure	12 (4%)	-	12 (14%)	-
Conduit root replacement	77 (23%)	-	77 (87%)	-
w/modified Cabrol	5 (2%)	-	5 (7%)	-
Ascending replacement	338 (100%)	249 (100%)	89 (100%)	-
Aortic arch				
Hemiarch[a] procedure	277 (82%)	202 (81%)	75 (84%)	0.630
Arch replacement	51 (15%)	40 (16%)	11 (12%)	0.491
Descending aorta	17 (5%)	14 (6%)	3 (3%)	0.575
Elephant trunk stage-I	6 (2%)	4 (2%)	2 (2%)	0.656
TEVAR	11 (3%)	10 (4%)	1 (1%)	0.300
Concomitant CABG	39 (12%)	26 (10%)	13 (15%)	0.334

Data are shown as mean ± standard deviation, number (percentage) or as [reported]. Statistical significant level was defined at $P \leq 0.05$ (bold values).
[a]Defined as the use of circulatory arrest including arch inspection, selective arch tear suturing, open distal anastomosis and partial/subtotal arch replacement.
RCP: retrograde cerebral perfusion; SACP: selective antegrade cerebral perfusion; w/: with; TEVAR: thoracic endovascular aortic repair; CABG: coronary artery bypass grafting.

group). One patient (age 50, male) underwent conduit graft replacement due to bleeding complications on the first postoperative day and expired intraoperatively. Another patient (age 70, female) developed progressive aortic valve regurgitation after 8.7 years and required RR. She died on the first postoperative day due to low cardiac output syndrome. Graft infection (age 53, male, 32 months postoperation) and sinus of Valsalva rupture (age 59, female, 11 months postoperation) were seen in one case each, and both required reoperation. Three patients developed aortic root aneurysm (age 61, 69, 70; 2 males; 10, 51 and 84 months postoperation); 2 of them underwent surgical correction, and 1 declined surgery. No new dissection within the root was noted. Strictly speaking, the bleeding, regurgitation and infection events are counted here but not directly related to sparing the aortic root.

In total, freedom from root events after 1, 5 and 10 years of follow-up was 99, 97 and 92% in the RS group and 100% each in the RR group, respectively (Fig. 3).

Of note, 2 patients with aortic valve resuspension and RS ascending replacement needed aortic valve replacement during follow-up.

DISCUSSION

The basic surgical management of AADA seeks primarily to avoid life-threatening aortic rupture and organ malperfusion, to close the entry tear and to re-establish blood flow to the aortic true lumen. More extensive treatment aims to eliminate secondary aortic dilatation, re-dissection and reoperation [2, 12]. However, a prophylactic/preventive approach entails certain additional operative risks. Regarding the proximal aorta, the question arises whether to replace the aortic root proactively (with need for coronary artery reimplantation) or to spare the root for the sake of surgical simplicity.

Clinical results

In the present study, a higher incidence of bleeding complications requiring re-exploration, low cardiac output and sepsis or severe inflammatory response syndrome were found in patients who underwent RR. Stroke and postoperative paresis were not influenced by the proximal aortic approach, as expected. Time on CPB and ischaemia time of the heart were extended in the RR group (75 and 61 min longer) reflecting the higher technical complexity. The technical complexity of RR originates from the surgical technique itself [6], and thus, procedure-typical and self-evident complications like bleeding and insufficient myocardial preservation or perfusion (resulting in low cardiac output) are the consequences, as found in the present and other studies [3, 5, 7].

Despite these noted morbidities, no difference in operative mortality was found between RR and the more conservative RS technique in the present study, despite a trend favouring the technically simpler approach (operative mortality 15 vs 20%),

Table 3: Postoperative outcome and follow-up

	Total population	Root sparing	Root replacement	*P*-value
Morbidities[a]				
Bleeding req. re-exploration	71 (22%)	42 (18%)	29 (34%)	**0.003**
Ventilation >48 h	133 (41%)	93 (39%)	40 (47%)	0.248
Tracheostomy	17 (5%)	11 (5%)	6 (7%)	0.403
Low cardiac output	57 (18%)	32 (14%)	25 (29%)	**0.002**
Mechanical assist	10 (3%)	7 (3%)	3 (4%)	0.728
Stroke/cerebral bleeding	48 (15%)	34 (14%)	14 (17%)	0.723
Paresis	23 (7%)	16 (7%)	7 (8%)	0.630
Malperfusion	32 (10%)	22 (9%)	10 (12%)	0.530
Haemofiltration	68 (21%)	45 (19%)	23 (27%)	0.125
Multi-organ failure	27 (8%)	16 (7%)	11 (13%)	0.108
Sepsis/SIRS	21 (7%)	11 (5%)	10 (12%)	**0.037**
Stays[b]				
ICU stay (days)	8.3 ± 10.8	7.8 ± 10.3	9.9 ± 12.1	0.198
In-hospital stay (days)	16.0 ± 15.0	14.7 ± 12.4	19.8 ± 20.3	**0.048**
Operative mortality[c]	56 (17%)	38 (15%)	18 (20%)	0.319
Exitus in tabula	11 (3%)	7 (3%)	4 (5%)	0.489
In-hospital mortality	53 (16%)	37 (15%)	16 (18%)	0.499
30-day mortality	53 (16%)	37 (15%)	16 (18%)	0.499
Survival				
Follow-up (months)	66.0 ± 45.5	66.4 ± 43.7	64.8 ± 50.9	0.782
1 year	80 ± 2%	81 ± 3%	76 ± 5%	–
5 years	76 ± 2%	77 ± 3%	73 ± 5%	–
Clinical follow-up[b,d] (months)	55.8 ± 44.2	55.3 ± 42.6	57.2 ± 48.9	0.601
Freedom from root events (months)	55.7 ± 44.3	55.2 ± 42.6	57.2 ± 48.9	0.601
1 year	99 ± 1%	99 ± 1%	100%	
5 years	98 ± 1%	97 ± 1%	100%	–
10 years	94 ± 3%	92 ± 4%	100%	–

Data are shown as mean ± standard deviation, number (percentage) or as [reported]. Statistical significant level was defined at $P \leq 0.05$ (bold values).
ICU: intensive care unit; req.: requiring; SIRS: systemic inflammatory response syndrome.
[a]Excluding patients who died intraoperatively.
[b]Including only discharged patients.
[c]Thirty-day mortality plus all in-hospital deaths after 30-days.
[d]Ten of 285 discharged patients (4%) were lost for clinical follow-up.

consistent with other studies (18 vs 21% [5]; 8 vs 23% [13]). This trend might be a reflection of higher disease complexity in the RR cohort, requiring more extensive proximal aortic replacement (treatment bias). Di Eusanio and the IRAD group identified, in their study of 1995 patients, younger age, Marfan's disease, bicuspid morphology, diseased aortic valve, coronary artery dissection, larger root diameter and dissection into the root portion as selection parameters towards RR, which might explain the frequently found distribution of ~1 : 2 to 1 : 3 (RR : RS) [3, 5, 12, 13]. Among those biasing factors, age (along with less incidence of coronary artery disease and arterial hypertension in the younger patients) differs by 5–8 years on average between both the groups [2, 3, 5, 12] and was shown to be independently associated with higher mortality in older patients [3].

Safety of a spared root

The aortic root grows slowly after ascending replacement by the RS technique, on average 0.40 ± 0.13 mm/year [ranging from 0.26 to 0.63 mm/year according to the initial size (25–60 mm)]. Hence, a guideline conformed RR (55 mm) would mathematically be indicated after 43 years (range 27–58 years). These findings are consistent with the data published by Rylski *et al.* [14]. They also found a very slow growth rate of 0.6 ± 1.1 mm/year at an initial size of 41.8 ± 6.3 mm (37.8 ± 4.9 mm in the present study), but noted a significantly higher growth rate of 1.3 ± 1.3 mm/year in patients requiring later reoperations compared with 0.2 ± 0.7 mm/year in those without. In comparison with the other portions of the aorta, the root of dissection patients appears to grow significantly slower [15] and equally to the aortic root of solely aneurysmal patients (Fig. 2).

Replacing the aortic root prophylactically aims for the prevention of secondary dilatation (incidence ~7–13%), recurrent dissection (3–7%), suture line and pseudoaneurysm (3–5%) and aortic valve insufficiency (3%), and for avoidance of reoperation (7–16%) after sparing the root [3, 13, 14]. The freedom from root reintervention is published at 99% after 3, 88–95% after 5 and 77–83% after 10 years [3, 5, 13, 16]. In the present study, the freedom from root events after the RS procedure was even higher at 97% after 5 years and 92% after 10 years. The count of secondary root dilatation and rupture was low, and no recurrent dissection was noted in the spared root portion. Even though the RS group was significantly older, survival showed no inferiority of an unreplaced root, which might have been expected due to later aortic events in the untouched proximal portion.

In our tabulation of later aortic events, uncommon as they were, we used a very liberal definition of late events. Bleeding, progressive aortic valve insufficiency and graft infection may not be appropriately reflective of negative impact from sparing the root.

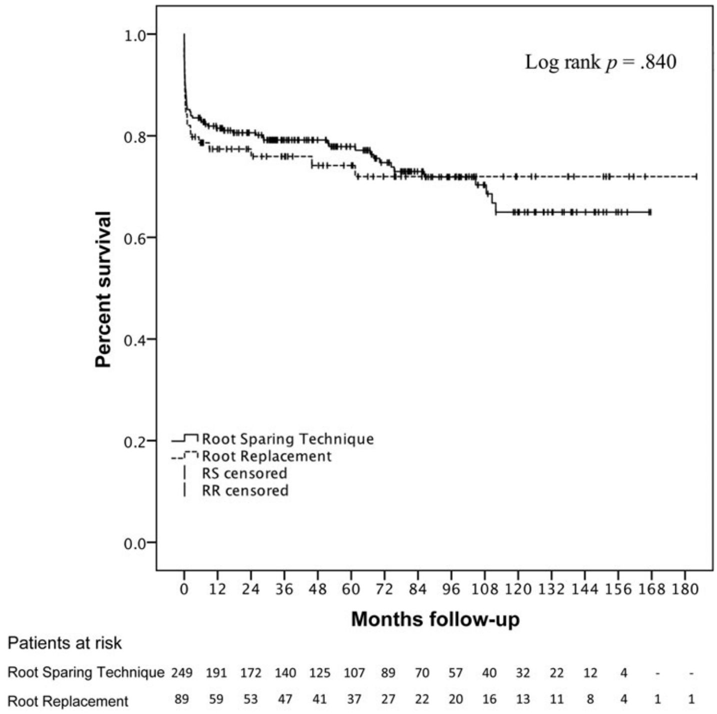

Figure 1: Kaplan–Meier survival estimation. RS: root sparing; RR: root replacement.

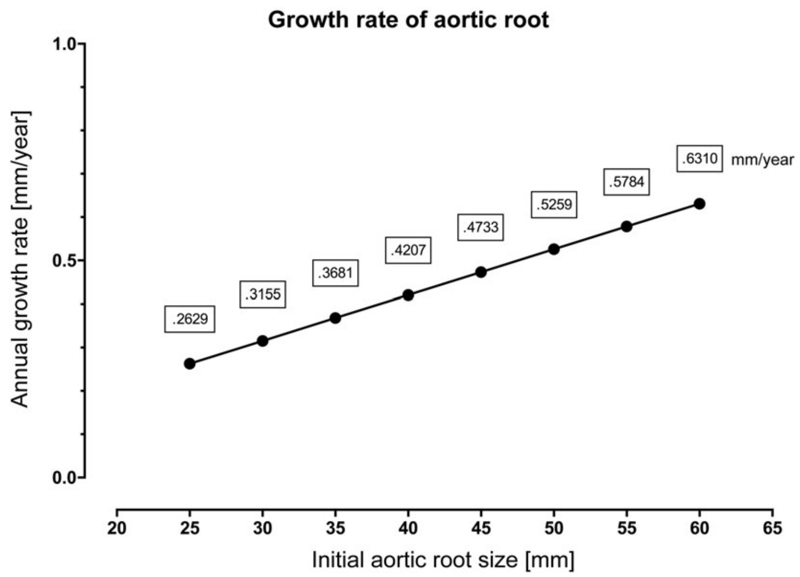

Figure 2: Growth rate of the aortic root. The figure presents the growth rates according to the initial diameter of non-syndromic patients with aortic dissection.

Balanced treatment of the proximal aorta

According to our results, both RS technique and RR can be performed with acceptable morbidity and mortality in AADA. Even though replacing the root prophylactically appears as a 'bulletproof' solution in the long run [2, 3, 12], a supracoronary ascending replacement with a spared root can be performed with excellent early and late results without major detriments in secondary complications and late survival. This is a very appropriate operation, except in Marfan syndrome or Marfanoid pattern root dilatation

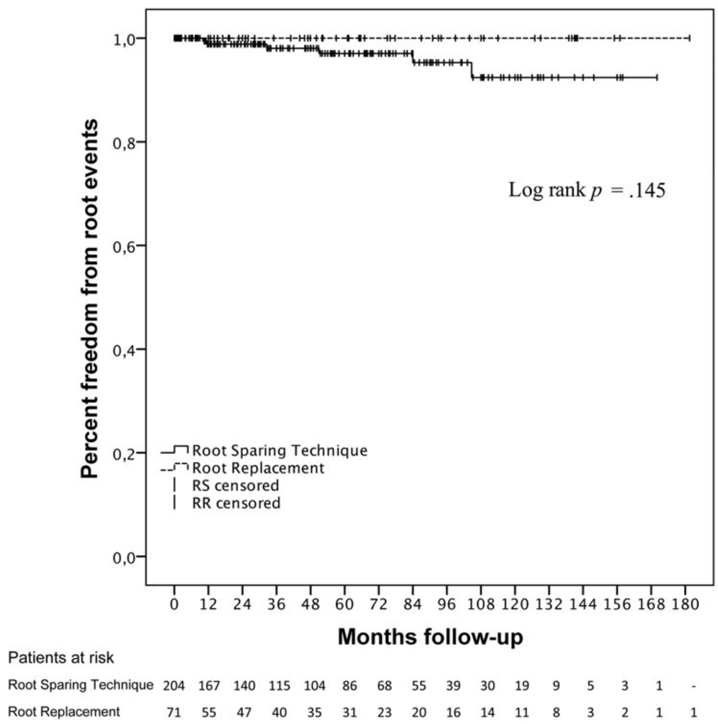

Figure 3: Freedom from root events. Root events include sinus of Valsalva rupture, recurrent root dissection, root aneurysm (>55 mm) and root replacement. RS: root sparing; RR: root replacement.

[5, 6]. In young patients, those with connective tissue disease (i.e. Marfan's syndrome), diseased valve with bicuspid morphology and root dilatation >40 mm, a RR is strongly recommended.

Limitations

The major limitation of our study is its retrospective nature, associated with inherent limitations of such analysis. The use of glue was limited in the included patients to adhering the layers, to sealing the anastomosis or stabilizing the anastomotic site; however, data regarding the application technique and the type of glue were incomplete and thus, excluded from further analysis. The treatment bias (more frequent aortic RRs in young, bicuspid and diseased valve patients [5]) also applies for the present study as in others and its impact on the growth rate (e.g. by treating bicuspid morphologies predominately with an RR) remains unknown; however, randomized studies comparing the treatment of the proximal aorta are lacking. The absence of this type of study and the fairly consistent trends seen in our patients' characteristics suggest that our findings are meaningful.

CONCLUSIONS

With regard to the proximal aorta, the technically simpler RS technique is associated with less postoperative morbidity, but similar operative mortality. During the follow-up course, the growth rate of the untouched root is slow, secondary root events are low and survival shows no inferiority. Thus, sparing the root, if not indicated separately [5], can be safely performed with a good integrity for a long period of time.

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APPENDIX. CONFERENCE DISCUSSION

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Dr E. Beckmann *(Hannover, Germany)*: My first question is about the two groups and the indication for surgery in the root replacement group. What was the indication for the root procedure in this group and were the native roots of the root sparing group completely native or were they dissected and glued?

Dr Peterss: The indication for root replacement at Yale, and also in Innsbruck, was 45 mm and above. This was certainly an indication to replace the root. In some cases, like in patients with bicuspid valve, and in younger patients (e.g. younger than 50 years), and in patients with affected coronary arteries, we tend to lower diameters, down to sometimes 40 mm. Can you please repeat your second part of the question?

Dr Beckmann: Was there any glue repair or was it completely native aortic tissue?

Dr Peterss: Patients with noted root repair by glue or similar techniques were excluded from this study. However, we don't have complete data about the concomitant application, but our institutional policy at Yale is to use Bio Glue between layers.

Dr Beckman: I think it is important to make a difference between native roots that are completely untouched and those that have been repaired due to dissection or dilation. So I am not sure whether it is fair to compare those two groups because basically there was an indication for root repair in the Bentall/David group but not in the other group. Can you comment on this?

Dr Peterss: You are absolutely right. The problem with the comparability arises from the retrospective character of this study. But as the previous speaker mentioned, a propensity score matching analysis will end up with a lower number of patients and in our case it was about 20 pairs. These propensity matched patients did not reflect the results of the total population, because these showed a much lower mortality and a much better outcome. That is the reason, why we just compared overall groups. A selection bias, or better stated, treatment bias affected most published studies. A prospective study which randomizes patients to root replacement and no root replacement is, to the best to my knowledge, not available in the literature so far. Such study might have the potential to answer the question whether to replace the root or not. Or, if you include large group populations into a study, a propensity matched score analysis will show statistically strong results. But finally, the more clinical relevant data you implement in the propensity score matching analysis, the lower is your number of pairs and the weaker is your statistical analysis in the end and thus the results.

Dr F. Emrich *(Leipzig, Germany)*: The increased hospital stay, do you think that's really only related to the longer cross-clamp and bypass times, or were the patients sicker?

Dr Peterss: I think in the end it's multifactorial. We have a higher incidence of preoperative resuscitation in the patients with a root replacement; we have a need for longer CPB time and a more prolonged need for catecholamine support. We also have a slightly increased incidence of stroke and a proportional increase of haemofiltration in this group. This reflects the multifactorial causes for hospital stay. But, as you've said, extended coronary bypass time caused by the root replacement itself is an important factor.

Dr Emrich: Another question. You excluded the syndromes. What about BAVs, did you look into those, whether they behaved differently?

Dr Peterss: We had about 5% of BAVs included in the study. These numbers are too low to do a separate analysis by tricuspid versus bicuspid morphologies. We know from the aneurysm patients—in total 102 analysed patients and who hopefully will be published soon—that there is no difference in the growth rate between tricuspid versus bicuspid valve morphologies in untouched roots after root-sparing procedures. Does this also apply for dissection? Honestly, I don't know, but it is highly expectable.

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EDITORIAL COMMENT

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To replace or not to replace: that is the question

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Keywords: Aortic root • Natural history • Aortic dissection • Supracoronary ascending replacement • Root replacement • Aortic events

Whether or not to the aortic root should be replaced during the emergency surgery in Type A dissection patients is a question as old as the surgical treatment of this acute aortic syndrome itself. Peterss *et al*. [1] published in this journal issue the results of

5.5 Elective surgery for ascending aortic aneurysm in the elderly: Should there be an age cut-off?

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Elective surgery for ascending aortic aneurysm in the elderly: should there be an age cut-off?†

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Abstract

OBJECTIVES: The objective of this study is to retrospectively analyse surgical outcomes in patients aged 75–79, and 80 and above.

METHODS: Between 2000 and 2015, 108 patients aged 75–79 (G_{75}, mean age 76.9 ± 1.5years) and 72 patients aged 80 and above (G_{80}, mean age 82.2 ± 2.1years) underwent elective aneurysm repair. Operative outcome and survival was compared with 727 contemporary younger counterparts aged <75 years (G_{Ctrl}, mean age 56.6 ± 11.7years).

RESULTS: Postoperatively, patients with advanced age showed a higher incidence of prolonged ventilation (G_{80} 21.4%, G_{75} 8.4%, G_{Ctrl} 2.9%; P < 0.001), low cardiac output syndrome (G_{80} 11.4%, G_{75} 1.9%, G_{Ctrl} 2.2%; P = 0.001), multi organ failure (G_{80} 2.9%, G_{75} 0%, G_{Ctrl} 0.1%; P = 0.022), haemofiltration (G_{80} 8.6%, G_{75} 0.9%, G_{Ctrl} 0.6%; P < 0.001), and infection (G_{80} 10.0%, G_{75} 6.5%, G_{Ctrl} 3.5%; P = 0.017). Operative mortality was significantly increased in the elderly (G_{80} 11.1%, G_{75} 3.7%, G_{Ctrl} 1.4%; P < 0.001). Mid-term survival differed significantly between the surgical groups. Multivariate regression analysis precluded age as an independent predictor of operative mortality.

CONCLUSIONS: Elderly patients showed a higher operative risk compared to their younger counterparts. However, age *per se* is no suitable indicator of surgical risk and well-selected patients with large threatening aneurysms may benefit from intervention.

Keywords: Aortic aneurysm • Aortic surgery • Advanced age • Seniors • Octogenarians • Septuagenarians

INTRODUCTION

Technical advances in recent decades have made aortic surgery safer and made surgical treatment of the aorta more accessible to patients, even with an increased risk profile and advanced age [1]. Nevertheless, aortic surgery—requiring prolonged cardiopulmonary bypass times and the possible need for hypothermia and circulatory arrest—still carries a substantial risk for older patients who have suffered biological deterioration of the cardiovascular, neurocognitive and renal systems via aging [2, 3]. Among elderly patients, mortality for thoracic aortic surgery ranges between 6 and 21% [2–7], depending on the definition of the term 'elderly' and the extent of surgery. Age has been shown to be an independent predictor of mortality both in cardiac surgery in general and in aortic surgery in particular [1, 3, 8]. But, as we explore aortic surgery in advanced age, are we pushing the limits too far or futilely?

The demographic structure of the Western countries has and will further change. According to the US Census Bureau, the proportion of octogenarians among the total population in the USA will increase from 3.7% (11.7million) in 2012 to 3.9% (13.2 million) for the 2020s and 7.7% (30.9 million) for the 2050s [9]. However, complex aortic surgery in the elderly and specifically whether there should be a cut-off age for aortic surgery remains debatable.

The aim of the present study was to evaluate the operative results of elective thoracic aortic aneurysm surgery in the elderly in the 21st century. We classified patients into two age frames (75–79 years, and ≥80 years), and compared to their younger counterparts.

†Presented at the AATS Aortic Symposium 2016, New York, NY, USA, 12–13 May 2016.
‡The first two authors contributed equally to this work.

MATERIAL AND METHODS

Study design

This study was designed as retrospective analysis of our institutional aortic database and was approved by the Human Investigation Committee of Yale University. All consecutive patients undergoing surgical repair between 2000 and 2015 were screened according to the inclusion and exclusion criteria.

The inclusion criteria included elective or urgent open aortic surgery due to aneurysm disease of the root, ascending or the arch portions of the aorta at any age. Exclusion criteria included: aortic dissection, free aortic rupture, intramural haematoma, penetrating aortic ulcer and thoracic aneurysm limited to the descending and the thoraco-abdominal segment of the aorta.

The total population was divided into three groups:

- Patients who underwent aortic surgery for thoracic aneurysm at age of lower than 75 ("control group", $\mathbf{G_{Ctrl}}$),
- Patients who underwent aortic surgery at advanced age, divided into
  - Age 75–79 years ($\mathbf{G_{75}}$), and
  - Age 80 years and older ($\mathbf{G_{80}}$).

We compared these groups according to demographic characteristics and co-morbidities, surgical data, and operative results and early outcome. Also, the predictors of mortality were evaluated statistically and mid-term survival was compared within the groups (G_{Ctrl}, G_{75} and G_{80}). Survival after discharge was determined by a multimodal follow-up assessment, as described recently by our group [10]. Either the date of death or the last confirmed clinical contact with the patient was counted as latest follow-up date.

Statistical analyses

Data are presented either as frequency distributions and percentages for categorical variables, or as mean ± standard deviation for continuous variables. The statistical difference between the three surgical groups (G_{Ctrl}, G_{75} and G_{80}) was tested using the Fisher's exact test for categorical variables and the ANOVA test for continuous variables. Predictors of operative mortality were investigated by both univariate analysis using Fisher's exact test or Student's t-test, and binary logistic regression including variables with a P-value $\leq$ 0.10 from the univariate analysis. Operative mortality was defined as in-hospital mortality plus patients who expired after discharge within the first 30 days post-surgery. The Kaplan–Meier survival estimation was used to analyse the postoperative survival and the Mantel-Cox log rank tests to compare the estimated survival of different populations. Statistical analysis was performed using SPSS® Statistics version 23.0 (IBM® Inc., Armonk, NY) in cooperation with the Departments of Economics and Preventive Medicine of Stony Brook University (Stony Brook, NY).

RESULTS

Population and demographic characteristics

In total, 907 patients who underwent surgery between 2000 and 2015 due to aortic root, ascending aorta or aortic arch aneurysm

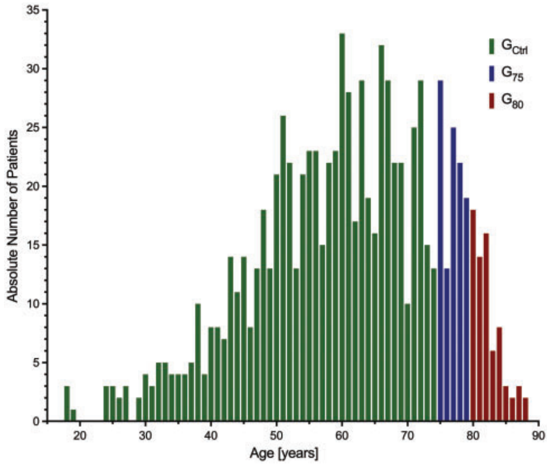

Figure 1: Caseload according to age between 2000 and 2015 at the Aortic Institute at Yale–New Haven.

are included in our institutional database (detailed age distribution is presented in Fig. 1). Among those, 727 were younger than 75 years (G_{Ctrl}; mean age 56.6 ± 11.7 years), 108 were aged between 75 and 79 years (G_{75}; 76.9 ± 1.5 years), and 72 were at age 80 and older (G_{80}; 82.2 ± 2.1). Gender and biometric data differed significantly between the groups, with an increase of female patients at higher ages and a decrease in body mass (each $P < 0.001$). The prevalence of congenitally bicuspid aortic valves decreases significantly with increasing age ($P < 0.001$). No Marfan's syndrome patient was found in the elderly groups ($P = 0.140$).

With regards to the co-morbidities, the incidence of atrial fibrillation ($P < 0.001$), coronary artery disease ($P < 0.001$), chronic renal failure ($P < 0.001$), dyslipidaemia ($P = 0.004$), arterial hypertension ($P = 0.002$), and pulmonary hypertension ($P < 0.001$) were just significantly increased at advanced age. Detailed data and inter-group comparison are presented at Table 1.

Operative data

Patients younger than 75 years more frequently received a root replacement compared to older patients ($P < 0.001$), while the root was spared in the majority of the advanced age groups. Distally, an extension into the arch—performing an open distal anastomosis/hemiarch replacement ($P < 0.001$) or a total arch replacement ($P = 0.011$) (both under straight deep hypothermic circulatory arrest)—was more often necessary in the elderly. Also, the need for concomitant coronary artery bypass grafting increased at higher ages ($P < 0.001$).

The cardiopulmonary bypass time was extended by 6.4 minutes on average in G_{75} and 11.8 min on average in G_{80} ($P = 0.004$), while the mean x-clamp time was comparable among all groups ($P = 0.844$). Hypothermic circulatory arrest time was also statistically prolonged ($P = 0.005$), but without clinical relevance. Femoral cannulation was the prevailing method within all groups; however, the frequency of direct aortic ($P = 0.004$) or axillary cannulation ($P < 0.001$) was higher with increasing age (as we avoid femoral cannulation when the thoraco-abdominal aorta is 'dirty' with arteriosclerosis). More details are shown in Table 2.

Table 1: Demographic characteristics

	Control group aged <75 years	Group 75	Group 80	*P*-value
n =	727	108	72	
Age [years]	56.6 ± 11.7	76.9 ± 1.5	82.2 ± 2.1	<0.001
Male gender	541 (74.4%)	65 (60.2%)	34 (47.2%)	<0.001
Biometry				
Weight [kg]	88.2 ± 19.6	76.2 ± 15.0	72.5 ± 12.9	<0.001
Height [cm]	174.8 ± 11.6	169.5 ± 11.0	167.9 ± 10.6	<0.001
BMI [kg/m^2]	28.9 ± 6.2	26.7 ± 4.5	25.7 ± 3.6	<0.001
BSA [m^2]	2.03 ± .26	1.89 ± .22	1.82 ± .20	<0.001
Maximal aortic diameter	52.3 ± 9.1	53.2 ± 10.0	58.3 ± 10.8	0.007
Aortic valve disease	439 (60.5%)	68 (64.5%)	40 (56.9%)	0.597
Stenosis	147 (20.2%)	24 (22.4%)	11 (15.3%)	0.502
Insufficiency	292 (40.3%)	44 (41.1%)	29 (40.3%)	0.992
Valve morphology				
Tricuspid	401 (55.2%)	84 (79.2%)	59 (92.2%)	<0.001
Bicuspid	321 (44.2%)	22 (20.8%)	5 (7.8%)	<0.001
Unicuspid	5 (.7%)	0 (-)	0 (-)	1.000
Congenital disorders				
Marfan	18 (2.5%)	0 (-)	0 (-)	0.140
Bovine arch	12 (2.0%)	1 (1.1%)	3 (4.2%)	0.384
Co-morbidities				
Atrial fibrillation	87 (12.0%)	21 (19.4%)	26 (36.6%)	<0.001
Hx of smoking	283 (39.0%)	39 (36.1%)	20 (28.2%)	0.183
Coronary artery disease	85 (11.7%)	23 (21.3%)	32 (45.1%)	<0.001
LVEF [%]	57.3 ± 10.2	57.8 ± 7.5	55.8 ± 9.7	0.706
COPD	60 (8.3%)	14 (13.0%)	10 (14.1%)	0.094
Chronic renal failure	36 (5.0%)	7 (6.5%)	13 (18.1%)	<0.001
Diabetes	73 (10.1%)	12 (11.1%)	3 (4.2%)	0.250
Dyslipidaemia	317 (43.7%)	63 (58.3%)	40 (56.3%)	0.004
Arterial hypertension	526 (72.6%)	88 (81.5%)	63 (88.7%)	0.002
Pulm. hypertension	13 (1.8%)	4 (3.7%)	8 (11.3%)	<0.001
Hx of stroke	29 (4.0%)	8 (7.4%)	0 (-)	0.040
Prev. cardiac surgery	66 (9.1%)	12 (11.1%)	8 (11.1%)	0.656

Data are shown as mean ± standard deviation, number (percentage) or as [reported]. The percentage values refer to the total number (*n*) of available information.
BMI: body mass index; BSA: body surface area; COPD: chronic obstructive pulmonary disease; Hx: history; LVEF: left ventricular ejection fraction; prev: previous; pulm: pulmonary.

Postoperative outcome and early mortality

The postoperative results and their analysis are presented in detail in Table 3.

The elderly patients showed multiple statistically significant deficiencies in postoperative outcome—a higher incidence of ventilation over 48 h ($P < 0.001$), low cardiac output syndrome ($P = 0.001$), myocardial infarction ($P = 0.045$), ventricular tachycardia ($P = 0.013$), sepsis ($P = 0.049$), multi organ failure ($P = 0.022$), haemodialysis ($P < 0.001$) and infection requiring antibiotic therapy ($P = 0.017$). Proportional differences (compared to the younger control group) were much higher pronounced in octogenarians rather than in patients aged between 75 and 79. Postoperative ICU stay was prolonged on average by 1.5 days in G_{75} and by 1.7 in G_{80} ($P < 0.001$). Respectively, hospital stay was also extended by 1.3 and 2.6 days ($P < 0.001$) on average.

Operative mortality was significantly increased at higher ages ($P < 0.001$).

Risk factor analysis

An univariate analysis isolated age ($P = 0.001$), bicuspid morphology ($P = 0.022$), bovine arch ($P = 0.049$), left ventricular ejection fraction ($P = 0.039$), coronary artery disease ($P < 0.001$), peripheral artery occlusive disease ($P = 0.018$), cardiopulmonary bypass time ($P < 0.001$), circulatory arrest time ($P = 0.002$), and concomitant coronary artery bypass grafting ($P = 0.014$) as significant predictors of operative mortality. Among these variables, none was found to be an independent risk factor in regression analysis.

Survival of the surgical groups

Mean follow-up was 74.9 ± 44.5 months for G_{Ctrl}, 49.0 ± 41.2 months for G_{75} and 44.3 ± 41.2 months for G_{80}, respectively. The survival differed significantly between the groups (Fig. 2) and decreased with increasing age ($P < 0.001$). 1-, 3- and 5-year survival is presented in Table 3.

DISCUSSION

The biology of patients in their last decades changes by the effects of aging. Alterations in the pulmonary system affecting all components of breathing (respiratory mechanic properties, gas exchange and the pulmonary vasculature) [11], changes in the cardiovascular system (e.g. left ventricular hypertrophy, impaired left ventricular contractility and relaxation) [12], deterioration of renal function (e.g. glomerulosclerosis, tubular atrophy and fibrosis) [13], hormonal imbalance between catabolic and anabolic

Table 2: Operative data

	Control group aged <75 years	Group 75	Group 80	P-value
n =	727	108	72	
CPB [min.]	149.1 ± 30.9	155.5 ± 30.5	160.9 ± 42.2	0.004
X-clamp [min.]	101.5 ± 28.8	100.2 ± 32.2	99.9 ± 32.0	0.844
HCA	373 (51.4%)	76 (70.4%)	59 (81.9%)	<0.001
HCA time [min.]	27.7 ± 6.7	29.7 ± 7.7	30.4 ± 7.8	0.005
HCA core temp. [°C]	18.8 ± .9	18.9 ± 1.2	18.7 ± 0.8	0.599
Procedure				
Bentall	307 (42.2%)	29 (26.97%)	13 (18.1%)	<0.001
Root sparing	420 (57.88%)	79 (73.1%)	59 (81.9%)	<0.001
w/AVR	262 (36.0%)	51 (47.2%)	28 (38.9%)	0.084
Hemiarch[a]	320 (44.1%)	60 (55.6%)	49 (68.1%)	<0.001
Arch Repl.	53 (7.3%)	16 (14.8%)	10 (13.9%)	0.011
ET stage-I	32 (4.4%)	8 (7.4%)	5 (6.9%)	0.239
Cannulation				
Aorta	39 (8.7%)	14 (17.7%)	14 (19.4%)	0.004
Femoral	396 (88.0%)	56 (70.9%)	48 (66.7%)	<0.001
Axillary	15 (3.3%)	9 (11.4%)	10 (13.9%)	<0.001
Prosthesis				
Mechanical[b]	400 (72.1%)	13 (16.3%)	4 (9.8%)	<0.001
Biological[b]	154 (27.7%)	67 (83.8%)	37 (90.2%)	<0.001
Size [mm]	23.4 ± 2.3	22.3 ± 2.2	21.9 ± 2.1	<0.001
Add procedure	147 (20.2%)	32 (29.6%)	31 (43.1%)	<0.001
CABG	95 (13.1%)	22 (20.4%)	25 (34.7%)	<0.001
Mitral valve	3 (.4%)	0 (-)	2 (2.8%)	0.088
Tricuspid valve	1 (.1%)	0 (-)	1 (1.4%)	0.167

Data are shown as mean ± standard deviation, number (percentage) or as [reported]. The percentage values refer to the total number (n) of available information.
AVR: aortic valve replacement; CABG: coronary artery bypass grafting; CPB: cardiopulmonary bypass; ET: elephant trunk procedure; HCA: hypothermic circulatory arrest; repl.: replacement; temp.: temperature.
[a] Hemiarch includes open distal anastomosis as well as hemiarch replacement, both with the need of HCA.
[b] Data refer to the number of implanted prosthesis.

Table 3: Postoperative outcome and survival

	Control group aged <75 years	Group 75	Group 80	P-value
n =	727	108	72	
Morbidities				
Bleeding	28 (3.9%)	6 (5.6%)	7 (10.0%)	0.059
Ventilation >48 h	21 (2.9%)	9 (8.4%)	15 (21.4%)	<0.001
Tracheostomy	3 (.4%)	1 (.9%)	1 (1.4%)	0.254
Low cardiac output	16 (2.2%)	2 (1.9%)	8 (11.4%)	0.001
Myocardial infarction	4 (.6%)	2 (1.9%)	2 (2.9%)	0.045
Ventr. tachycardia	8 (1.1%)	3 (2.8%)	4 (5.7%)	0.013
AV block III°	16 (2.2%)	5 (4.7%)	4 (5.7%)	0.062
Pacemaker	26 (3.6%)	8 (7.5%)	5 (7.1%)	0.067
Multi organ failure	1 (.1%)	0 (-)	2 (2.9%)	0.022
Sepsis	2 (.3%)	0 (-)	2 (2.9%)	0.049
Stroke	8 (1.1%)	2 (1.9%)	2 (2.9%)	0.163
Renal failure	11 (1.5%)	2 (1.9%)	9 (12.9%)	<0.001
Haemodialysis	4 (.6%)	1 (0.9%)	6 (8.6%)	<0.001
Infection	25 (3.5%)	7 (6.5%)	7 (10.0%)	0.017
Stay [days]				
Intensive care unit	3.0 ± 2.9	4.5 ± 5.8	4.7 ± 5.3	<0.001
In-hospital	6.4 ± 4.3	7.7 ± 6.3	9.0 ± 8.1	<0.001
Operative mortality	10 (1.4%)	4 (3.7%)	8 (11.1%)	<0.001
Intraop. mortality	1 (.1%)	1 (.9%)	0 (-)	0.358
In-hospital mortality	8 (1.1%)	2 (1.9%)	8 (11.1%)	<0.001
30-day mortality	10 (1.4%)	4 (3.7%)	8 (11.1%)	<0.001
Survival				
1-year	96 ± 1%	92 ± 3%	79 ± 5%	
3-year	93 ± 1%	78 ± 5%	67 ± 6%	
5-year	90 ± 1%	71 ± 5%	58 ± 7%	

Data are shown as mean ± standard deviation, number (percentage) or as [reported]. The percentage values refer to the number of patients, who survived the first postoperative 24 h.
h: hours; ventr.: ventricular.

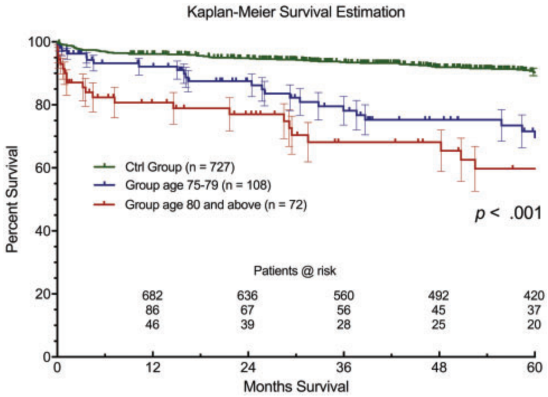

Figure 2: Kaplan–Meier survival estimation according to the age-related surgical groups.

hormones towards the catabolic side, and neurocognitive dysfunction and neurovascular changes are commonly observed with increasing age [14, 15].

Thus, not unexpectedly, the biometric data and incidence of preoperative co-morbidities differ between the age-related groups. The elderly groups showed preserved left ventricular function and no significant difference in the frequency of chronic obstructive pulmonary disease, diabetes, history of stroke, and previous cardiac surgery compared to their younger counterparts, which might haul out these variables as subjective denial criteria for older patients in our institute.

The aging changes in biology are also reflected in the postoperative morbidities. Patients at higher ages suffered from multiple complications affecting the pulmonary, cardiovascular, renal, immunologic and multiple organ systems. However, the proportional differences were markedly less pronounced in patients aged 75–79 years rather than 80 and above. These data conform to studies in the literature [6, 7, 8, 16]. Bleeding complications ranged between 3–15% in these studies and were found in 5.6–10.0% in the present study, likely reflecting increased tissue fragility at higher ages. Interestingly, stroke rate in the present study, usually reported with significantly higher incidence in elderly (between 2–9% [3, 4, 6–8]), was low in the group aged ≥ 80 years (2.9%) and did not differ to their younger counterparts (1.1%), despite the fact that 81.9% of the elderly underwent deep hypothermic circulatory arrest of 30.4 min on average. However, a positive selection of healthier elderly patients in that age group might have influenced these results.

Operative mortality, as the classical surgical surrogate of successful treatment, increased significantly at higher ages. While patients aged between 75 and 79 again showed much lesser increase of operative mortality, ages of 80 and above suffered from surgery-associated deaths of up to 11.1%. Generally, mortality (in-hospital, 30-day or operative) ranges in the literature between 6 and 16% for general cardiac and aortic surgery and age was frequently described as independent predictor. Safi and colleagues identified an age of 72 as cut-off for increased mortality, while the present study showed good results in that specific age group. The present study did not identify age as independent predictor of postoperative mortality—representing outcome at higher ages as multifactorial process-, and thus, according to our data, we would specify the border of increased risk at a higher age, around 80 years.

However, even if the operative risk for morbidity and mortality increases at the age of 80, surgical intervention in threatening aneurysms with larger diameter may potentially eradicate the higher risk from aortic rupture and dissection and thus, restore patient outlook to baseline. This hypothesis is supported by the literature reporting similar or better survival of surgically intervened patients compared to medically treated patients, and freedom from aortic events due to intervention [17, 18].

However, for the elderly, restoring survival is not sufficient without maintenance of quality of life [16, 19]. Also, as frailty measures have emerged, surgeons have quantified that chronological and biological age as not identical [20, 21]. Such factors enter into surgical decision for thoracic aortic disease as well as general conditions for surgery.

LIMITATIONS

This is a retrospective study with the inherent limitations for such analysis. Patients undergoing aortic surgery at higher age usually underlie a positive selection bias, as described above. Beside the denial by the patients themselves, the rejection by the surgeon due to more complex co-morbidities was one of the common causes of the decision toward medical treatment and thus, might influence the survival of the particular subgroup.

CONCLUSIONS

Patients undergoing aortic surgery at advanced age are subject to higher operative risk, particularly at the age of 80 and above. However, in the present study, age *per se* is no suitable indicator of operative outcome and thus, a strict age cut-off cannot be deduced thereof. Surgery in well-selected octogenarians with 'urgent' and threatening aortic sizes potentially restores survival and patients may benefit from intervention, even above age 80.

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5.6 Acute type A dissection in octogenarians: Does emergency surgery impact in-hospital outcome or long-term survival?

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Acute type A dissection in octogenarians: does emergency surgery impact in-hospital outcome or long-term survival?†

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Abstract

OBJECTIVES: Surgical therapy for acute aortic dissection type A (AADA) in octogenarians carries high morbidity and mortality. The role of isolated medical treatment in this setting is controversial. The aim of this study is to determine whether risk of surgery for AADA outweighs risk of death from medical treatment only.

METHODS: From 2002 to 2015, 90 consecutive octogenarians (mean age, 83.5 ± 3 years) were treated for AADA at three institutions: 67 patients underwent surgery, 23 patients received medical treatment. Analysis of early and late outcome was performed.

RESULTS: Patients in the medical treatment group were significantly older than in the surgical group (84.9 ± 3.7 vs 83 ± 2.5 years, $P = 0.008$) and in a more critical state. In patients undergoing surgical repair, perioperative mortality was 14.9% ($n = 10$). Rate of prolonged ventilation (63.2% vs 5.9%; $P < 0.001$) and renal failure (35.1% vs 5.9%, $P = 0.029$) was significantly higher in the surgical group. Thirty-day survival was impaired in the medical treatment group (34.8% vs 61.2% in the surgical group; $P = 0.032$). Coronary artery disease (OR 3.95, 95% CI 1.16–13.49; $P = 0.029$) and complicated dissections (OR 5.28, 95% CI 1.48–18.88; $P = 0.010$)—composite variable of preoperative resuscitation, neurological injury and malperfusion—emerged as independent risk factors for 30-day mortality in the surgical group. There was no difference in long-term survival.

CONCLUSIONS: Emergency surgery for AADA in octogenarians is associated with relatively high intraoperative mortality and may reasonably be avoided in patient with complicated presentation. Despite better immediate survival after surgery, long-term survival does not differ between medical and surgical patients, reflecting the extremely advanced point in life cycle octogenarians.

Keywords: Octogenarians • Type A aortic dissection • Surgery • Medical treatment • Survival benefit

INTRODUCTION

The steadily increasing life expectancy carries substantial increase of octogenarians in Western society (up to 3-fold by 2050, according to recent data of the US Census Bureau) [1]. Concurrently, the number of elderly patients undergoing elective as well as emergent cardiac surgical procedures is increasing. A population-based study by Howard *et al.* [2] predicts a proportion of patients over the age of 75 suffering from aortic dissection of over 50% in future years. Surgical therapy for acute aortic dissection type A (AADA) in octogenarians carries high morbidity and mortality. In order to improve the outcome of such advanced age patients, a modified surgical treatment towards a less invasive replacement has been suggested [3]. Although the literature still considers surgery as the primary option, little is known about outcome of AADA in octogenarians when treated medically [4–7]. Therefore, this study compares early and late outcome in octogenarians suffering from AAD undergoing either medical or surgical treatment. The aim of this study is to determine whether risk of surgery for AADA outweighs risk of death from medical treatment only.

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‡The first two authors contributed equally to this study.

MATERIALS AND METHODS

Study design

Three institutional surgical databases (Department for Cardiac Surgery, Medical University Innsbruck/Austria, Department for

Table 1: Baseline characteristics and preoperative data

Variable	Surgical treatment (*n* = 67)	Medical treatment (*n* =23)	*P*-value
Age (years)	83.0 ± 2.5	84.9 ± 3.7	**0.008**
Male sex	33 (43.3)	10 (43.5)	0.809
Body mass index (m^2)	26.1 ± 5.3	28.1 ± 7.8	0.211
Comorbidities			
Hypertension	54 (80.6)	19 (82.6)	1.000
Diabetes	15 (22.4)	2 (9.1)	0.221*
Coronary artery disease	18 (26.9)	9 (40.9)	0.285
Hyperlipidaemia	24 (37.3)	12 (54.5)	0.213
Peripheral vascular disease	9 (13.4)	0 (0)	0.105*
Preoperative creatinine level	1.4 ± 1	1.4 ± 1	0.959
Previous cerebrovascular accident	6 (8.9)	4 (18.2)	0.260*
COPD	8 (11.9)	7 (31.8)	**0.047***
De Bakey classification			
Type I	36 (53.7)	15 (65.2)	0.465
Type II	31 (46.3)	8 (34.8)	0.465
Malperfusion syndrome	11 (16.7)	7 (30.4)	0.226*
Neurological symptoms at presentation	6 (9.1)	6 (26.1)	0.069*
Preoperative intubation	5 (7.6)	5 (21.7)	0.116*
Pericardial effusion	24 (35.8)	17 (73.9)	**0.003**
Tamponade	20 (29.9)	4 (17.4)	0.287
Preoperative CPR	5 (7.6)	1 (4.3)	1.000*
Redo surgery	8 (11.9)	4 (17.4)	0.494*

COPD: chronic obstructive pulmonary disease; CPR: cardiopulmonary resuscitation. Results are given in mumber (%) or mean ± standard deviation. Significance level (for bold values) was $P < 0.05$.
**P*-value based on Fisher's exact test.

Cardiac Surgery, Leipzig Heart Centre/Germany, Yale Aortic Institute, New Haven/USA) were retrospectively reviewed to identify patients aged older than 80 years suffering from AADA between 2002 and 2015. Patients' charts and imaging data were analysed and survival follow-up was evaluated. The institutional review boards approved this study.

Between January 2002 and August 2015, a total of 90 octogenarians (mean age, 83.5 ± 3 years) were admitted due to AADA to three international institutions. Patients were divided into two groups based on the treatment (*n* = 67 surgical treatment, *n* = 23 medical therapy). Patient characteristics are listed in Table 1.

Treatment groups

All patients were evaluated by a cardiac surgeon. The decision for surgical or medical treatment was primarily driven by the patient's condition at presentation and comorbidities. After evaluation of imaging studies and risk assessment, risks and benefits of surgical treatment were explained to the patients and their families and a final decision was made.

If surgical treatment was therapy of choice, the patient was taken to the operation room and induction of anaesthesia was performed immediately. Once cardiopulmonary bypass (CPB) was established, systemic cooling was initiated. Depending on the extent of the dissection and the surgeon's consideration, the distal anastomosis was either performed via aortic cross clamping or in an open fashion during circulatory arrest. After careful evaluation of the primary entry site, replacement of the aortic root, the ascending aorta, the aortic arch or a combination of these structures was performed. Aortic arch replacement was performed in case of a pre-existing arch aneurysm or an entry tear or ulceration located in the convexity of the aortic arch, which could not be excluded by partial arch replacement.

In case of medical therapy, all patients were initially shifted to the intensive care unit. Once haemodynamic monitoring was instituted, hypertensive patients received intravenous vasodilators and beta-blockers in order to decrease blood pressure and vascular stress. In addition, pain medication or light sedation was administered to achieve maximal comfort for the patient.

Outcome and follow-up analysis

Patients who died intraoperatively or within 24 h postoperatively were defined as early deaths (*n* = 16, 17.8%). Renal failure was defined as the need for either haemofiltration or dialysis due to acute renal insufficiency. Tracheotomy was performed in patients with prolonged ventilator support and failure to be weaned from the respirator. Postoperative neurological injury was defined as permanent new neurological deficit and/or brain injury detected on computed tomography (CT) or magnetic resonance imaging (MRI) scan. Follow-up information was obtained using Social Security Death Index, telephone interviews or outpatient clinic visits.

Statistical analysis

Statistical analysis was performed using SPSS 23.0 (SPSS Inc., Chicago, IL, USA). Categorical variables are expressed as frequency distributions and percentages; continuous variables are expressed as mean ± standard deviation. Chi-square test was used for categorical variables. If observed frequencies were <5, Fisher's exact test was used for categorical variables. Student's *t*-test was applied for continuous variables.

In order to adjust for selection bias a regression model was created for 30-day mortality as well as overall mortality: all factors showing significant difference between the two treatment groups in univariable analysis or $P < 0.10$ were considered for multivariable analysis. Multivariable analysis did not remain statistically significant after adjusting for the following factors: age, chronic obstructive pulmonary disease (COPD), pericardial effusion and preoperative neurology (Table 2).

Factors influencing 30-day mortality in the surgical group were explored by separate univariable analysis in a first step. Factors showing significant influence or clinical relevance were then taken to multivariable analysis using logistic regression. For description of long-term survival Kaplan–Meier curves were calculated; groups were tested by log-rank and Gehan–Breslow–Wilcoxon test to determine differences in early and long-term survival. Differences in survival rates during the early period are reflected by Gehan–Breslow–Wilcoxon test, whereas P-value of log-rank test is based on differences in long-term survival.

For comparing survival after discharge with expected survival of an age- and gender-adjusted normal population, each patient was individually matched and followed according to life-table survival data from the Centers of Disease Control and Prevention for intercensal years 2000 [8]. A single-sample log-rank test was employed for assessing the difference between operative and expected survivals. The life-table year was selected to correspond to the mean and median year of surgery.

RESULTS

Patient characteristics

Female gender was predominant in both treatment groups. Patients in the medical treatment group were significantly older than surgical patients. In terms of risk factors and comorbidities groups only differed in rate of COPD. Patients in the medical treatment group were in a more critical state at point of admission with significantly higher rates of pericardial effusion and a strong trend towards more neurological symptoms. Details are given in Table 1.

Surgical therapy

Out of 67 patients in the surgical treatment group, three patients (4.5%) died from aortic rupture during induction of general anaesthesia and before initiation of CPB could be performed.

In most patients, arterial cannulation was performed through the right axillary artery ($n = 32$, 50%) or the femoral artery ($n = 22$, 34.4%). The ascending aorta was used for cannulation only in rare cases ($n = 10$, 15.6%). In most patients ($n = 52$, 81.3%), deep (18–21 °C) or moderate (24–27 °C) hypothermic circulatory arrest was performed in order to allow an open distal anastomosis. Mean circulatory arrest time was 25.3 ± 18.5 min. In 12 patients (18.8%), a less invasive quick replacement was performed via aortic cross clamping. Most of these patients ($n = 8$, 66.7%) presented with De Bakey type II dissections. For all patients, mean aortic cross clamp time was 90 ± 48.6 min, mean CPB time was 177.6 ± 69.1 min. An isolated ascending replacement was performed in most patients ($n = 52$, 81.3%). Root replacement was necessary in six patients (9.4%) and six more patients (9.4%) needed supplemental aortic valve replacement. Aortic arch replacement was limited to eight patients (12.5%) and coronary artery bypass grafting to 10 (15.6%).

In-hospital outcome

Overall 16 patients (17.8%) died within 24 h after admission to the hospital with no difference between the treatment groups (surgical $n = 10$, 14.9% vs medical $n = 6$, 26.1%; $P = 0.342$). Table 3 gives details on causes of early deaths. In the remaining 74 survivors, prolonged ventilation (more than 48 h) was more frequently necessary in patients undergoing surgical therapy ($n = 36$, 63.2% vs medical $n = 1$, 5.9%; $P < 0.001$); 11 patients (19.3%) underwent tracheotomy after surgical treatment due to weaning

Table 3: Causes of early deaths

Variable	Surgical treatment ($n = 10$)	Medical treatment ($n = 6$)
Aortic rupture	4 (40)	2 (33.3)
Heart failure	4 (40)	3 (50)
Diastolic failure due to tamponade	1 (10)	3 (50)
Coronary malperfusion	3 (30)	0
Hypovolaemic shock	1 (10)	0
Uncontrollable bleeding	2 (20)	0
Multiorgan failure	0	1 (16.7)

Results are given in number (%) or mean ± standard deviation.

Table 2: Multivariate regression analysis for 30-day mortality and Cox regression model for overall survival

	30-Day mortality			Overall survival		
	OR	95% CI	P-value	HR	95% CI	P-value
Surgical treatment	0.62	0.19–2.02	0.426	0.88	0.42–1.82	0.722
Age	1.18	0.99–1.40	0.60	1.09	0.99–1.20	0.068
Pericardial effusion	1.48	0.57–3.82	0.418	1.30	0.74–2.29	0.368
Preoperative neurology	2.49	0.60–10.31	0.208	0.69	0.30–1.58	0.377
COPD	0.98	0.29–3.37	0.980	1.30	0.65–2.61	0.458

CI: confidence interval; COPD: chronic obstructive pulmonary disease; HR: hazard ratio; OR: odds ratio.

Table 4: In-hospital complications

Variable	Surgical treatment	Medical treatment	*P*-value
Ventilation > 48 h	36 (63.2)	1 (5.9)	**<0.001**
Tracheotomy	11 (19.3)	0 (0)	0.059*
Low output syndrome	12 (20.7)	9 (40.9)	0.066
Multiorgan failure	11 (19)	0 (0)	0.060*
Sepsis	5 (8.8)	0 (0)	0.583*
Stroke	11 (20)	2 (10.5)	0.498*
Haemofiltration/haemodialysis	20 (35.1)	1 (5.9)	**0.029***

Results are given in number (%). Significance level (for bold values) was $P < 0.05$.
**P*-value based on Fisher's exact test.

failures. Also, rate of renal failure requiring haemofiltration or haemodialysis was significantly higher in the surgical group [$n = 20$, 35.1% vs $n = 1$, 5.9%; $P = 0.029$ (according to Fisher's exact test)]. In 11 patients (19.3%) in the surgical group imaging (CT or MRI scans) revealed strokes. Three of these patients had neurological abnormalities at admission before surgery. Mean ICU as well as in-hospital stay was longer in the surgical group (10.5 ± 1.3 vs 3.8 ± 0.8 days in the medical group; $P = 0.015$ for ICU stay, 15.7 ± 14.2 vs 5.4 ± 4.3 days in the medical group; $P = 0.001$ for in-hospital stay).

Further morbidities are listed in Table 4.

In-hospital mortality did not differ significantly between the groups (32.8% for surgical vs 47.8% for medical treatment; $P = 0.218$). However, 30-day mortality was significantly higher in the medical treatment group (65.2% vs 38.8% in the surgical group; $P = 0.032$).

Age-adjusted multivariable analysis identified coronary artery disease (OR 3.95, 95% CI 1.16–13.49; $P = 0.029$) and complicated AADA (OR 5.28, 95% CI 1.48–18.88; $P = 0.010$)—defined as a composite variable including preoperative cardiopulmonary resuscitation, preoperative neurological injury or preoperative malperfusion syndrome—as independent risk factors for 30-day mortality in patients undergoing surgical treatment.

Late survival

Mean follow-up period was 19.6 ± 32.2 months. Overall survival of octogenarians suffering from AADA, regardless of treatment, was 42.7 ± 5.3%, 33.1 ± 5.4% and 26 ± 5.6% at 1, 3 and 5 years. Figure 1 illustrates impaired overall survival in octogenarians suffering from AADA when compared with an age- and gender-matched control.

Surgical treatment leads to improved survival when compared with medical treatment (Breslow $P = 0.030$), with 1- and 3-year survival of 48.5 ± 6.2% and 37.5 ± 6.5% for the surgical group and 25.4 ± 9.2% and 19 ± 8.8% in the medical group. Beyond 5 years, survival does not differ between the two treatment groups (log-rank $P = 0.077$). Further details are shown in Fig. 2.

DISCUSSION

This study presents the experiences of three large and specialized aortic centres in Europe and North America and thus reflects one

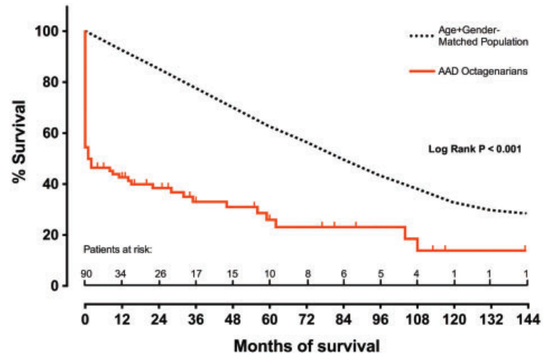

Figure 1: Actuarial survival of octogenarians suffering from acute aortic dissection type A compared with age- and gender-matched US population.

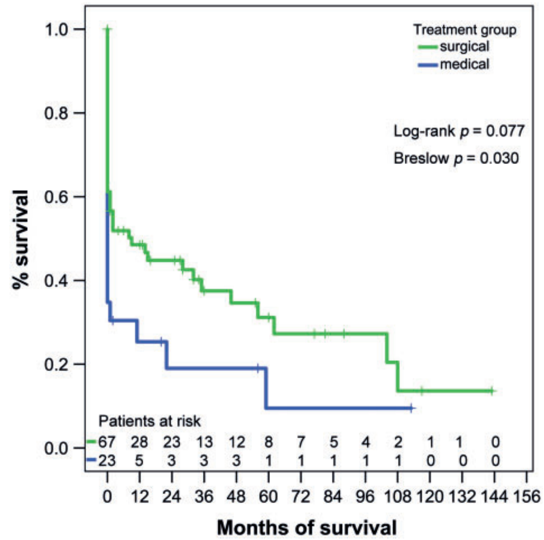

Figure 2: Overall survival of octogenarians suffering from acute aortic dissection type A undergoing surgical repair versus medical treatment.

of the largest octogenarian cohorts suffering such disease. The natural course and prognosis of AADA is known to be devastating; complications often occur before admission or in an early phase, frequently associated with fatal outcome.

Octogenarians with AADA are frequently in a severe clinical state when admitted to the hospital and carry a broad spectrum of comorbidities due to their age. A multicentre study by Piccardo *et al.* [6] reports a rate of complicated dissections (defined as neurological deficits, mesenteric ischaemia or cardiopulmonary resuscitation) of 20.2%. The extent of early complications is also confirmed by Neri *et al.* [7], showing high rates of organ malperfusion (up to 41%) or cardiac tamponade (in 62%) of octogenarians. The impact of organ malperfusion or haemodynamic instability is severe, even more so in this advanced age population [9, 10].

In this study, beside presence of coronary artery disease, complicated dissection emerged as independent risk factors for 30-day mortality after operative repair in this study, emphasizing the importance of the preoperative state of the patients. These factors reflect the surgeon's dilemma of finding a reasonable

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treatment for a fragile patient already suffering from complications of a lethal cardiovascular disease.

Although the role of surgical treatment of AADA in octogenarians has been controversial, most centres still promote surgery as the best treatment option for AADA in octogenarians based on the dismal natural history of the disease. However, surgical therapy for AADA is associated with high intra- or perioperative mortality in octogenarians, with in-hospital mortality rates up to 83% [7]. Almost 15% of patients expired during surgery in the present series, whereas other groups report even higher rates up to 33% [7]. High surgical mortality results most frequently from either aortic rupture or uncontrollable bleeding. Although survival is the primary aim of surgical treatment of AADA patients, surgeons need to recognize that aggressive therapy still leads to lethal outcome in many octogenarians. In patients at this age, the combination of preoperative conditions (comorbidities and complications), age and frailty themselves inflict poor early outcome.

Medical treatment as an alternative option for AADA is often preferred in patients with advanced age or multiple comorbidities but is associated with very poor outcome. In this study cohort, age was an important but not the only criteria for medical treatment. Factors influencing surgeons to recommend or choose medical treatment were either comorbidities or the patient's status at admission (neurological impairment, intubation or resuscitation before admission). In almost 30% it was the patient or the patient's family, who declined surgical repair. Survival rates of only 70–72% within the first 24 h after the event reflect the grave natural prognosis of the disease [11, 12]. Data from the International Registry of Acute Aortic Dissection revealed a 30-day mortality of 58% in patients treated medically, regardless of age [12]. The role of medical treatment especially in elderly patients has been investigated in very small cohorts only. Trimarchi *et al.* [5] reported an in-hospital mortality of 55% in 29 octogenarians receiving medical treatment. Slightly higher in-hospital death rates have been found by Yanagisawa (57%) and Hata (60.7%) as well as this study (65.7%) [13, 14].

However, in this study, we found 30-day survival was significantly better in the surgical group, although postoperative complications were high in surgical patients. In AADA and especially in older patients with limited capacity, the first few days after surgical repair seem to divide survivors from non-survivor. In-hospital outcome was dismal in both treatment groups and early postoperative mortality rates were tremendously high. Nevertheless, once surgical patients could be stabilized in the early postoperative phase, survival improved in contrast to patients receiving medical treatment. Thirty-day survival data reflect this trend in both treatment groups. Unfortunately, survival in surgical patients was accompanied with high rates of postoperative complications. In addition to a trend towards higher rates of strokes, more than 35% of patients in the surgical group suffered from renal failure requiring haemofiltration or dialysis. Obviously, these complications do significantly impact quality of life.

Although the usual measures of treatment outcome (postoperative morbidity, mortality and survival) favour surgical therapy, regenerative capacity also becomes a limiting and striking factor in the elderly. A complete restoration of autonomous life postoperatively is highly doubtful, as shown previously [15]. Given these circumstances and the finding of our study, conservative treatment for AADA in the elderly may be appropriate in many cases, especially with comorbidities or complicated initial presentation.

Limitations of the study

This study has a number of limitations. First, data acquisition and analysis in the different databases was done retrospectively. Second, despite the multicentricity of the study, the absolute number of patients remains small. Especially the group of octogenarians receiving medical treatment is limited. Therefore, uni- or multivariable calculations of risk factors for hospital mortality could only be performed for the surgical group. Third, only octogenarians who were admitted or referred to the three study centres alive were included. The hospital databases miss the substantial proportion of octogenarians suffering from AADA but expiring at home or on the way to the hospital. Fourth, follow-up period was limited due to the advanced age of the study population. Survival was the only study end-point evaluated in the follow-up period. Quality of life and functional outcome would be interesting factors to be evaluated. Most importantly, the choice of treatment—medical versus surgical—was not randomized. This certainly accounts for a strong selection bias in the study, reflecting the consulting surgeon's assessment of the patient's chances of surviving surgery and deeming the more seriously ill population into the medical treatment group.

CONCLUSIONS

We compared medical and surgical treatment of acute ascending aortic dissection in octogenarians. Surgical treatment is associated with lower 30-day mortality rates and better early survival when compared with medical treatment. Long-term survival beyond 5 years does not differ, reflecting the extremely advanced age point in the life cycle. Individualized preoperative evaluation and selection of these patients remain essential. Respecting and accepting the disease—acute ascending aortic dissection—as a potential mode of death should be considered, especially in complicated dissections. Medical treatment represents a reasonable option in octogenarians.

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