Endovascular Neurosurgery: a history of electricity balloons, wires and glue

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September 18, 2009
William Harvey (1578 – 1657)
Thomas Willis, London 1663
Endovascular: procedures and techniques that use a vessel (artery or vein) as the route to establish diagnosis or treat diseases
1864 Moore, in England performed an autopsy on a sailor that died from a gunshot to the chest. Autopsy revealed the bullet located at the thoracic aorta embedded in fibrin...
“The foreign body which according to our current knowledge would produce least irritation is wire. If a large quantity were coiled in an aneurysm it would attract fibrin as the twigs do in whipping freshly drawn blood, support the mass which it entangled and lead to the cavity of the aneurysm being eventually filled. The wire might be passed in through a small cannula with care not to leave the last end in the minute wound, and not to direct a coil into the orifice of the artery”

Moore, 1864
Moore, Introduced 26 yd of wire in a thoracic aneurysm obtaining immediate reduction of blood pressure and decrease in size. Patient died from sepsis...

“the interior of the tumor was filled, for the most part, with a fibrinous coagulum, enveloping and embedded in the coils of wire and firmly adherent to the walls”
Moore recognized that subtotal packing of the aneurysm would not protect from hemorrhage and distal embolization of the coil could cause thrombus.
1866  Duncan described the “electropuncture of aneurysms”

Multiple local complications, skin necrosis, abscess formation, etc
50% cure rate
Vs. 33% mortality vessel ligation
14% mortality

1871  Domville 14 In of iron wire into an thoracic aneurysm

1877  Montenovesi used watch-springs to pack aneurysms

1897  Stewart packed gold wires into syphilitic aneurysms
1879  Corradi recognized the use of metallic coils + electrical current

10 ft of wire “75 parts of cooper and 1000 parts of 1000 of silver” applied 75mA for 1 hr

Multiples attempts with high incidence of failures... different current settings ... multiple stages...
Direct approach using trocars to deliver the wire, Linton

200 ft of #30-gauge stainless wire
1895  Röentgen described x-ray
X for *unknown*

1901  Received the Nobel Prize in Physics
1896 Haschek & Linderthal demonstrated the arteries of the hand on a corpse

Teichmann mixture
Lime, mercury, petroleum
1911  Matas described the importance of assessing tolerance and increasing collateral vessels before ligations.

wire insertion is

“semisurgical or quasimedical”

1916  “appeal to us more as placebos than as real remedies”
1919 Knauer, started intraarterial (direct puncture) injections of neo-salvaran to cure paralysis of the insane
Antonio Caetano de Abreu Freire

- MD, neurologist, writer
- Politically active as a student,
- Run for president
- Became a member of parliament
- Was Portugal’s signatory of Treaty of Versaille, Minister
- Return to the academy at 51 yo

Egas Moniz de Ribadouro, fought against the Moors in the 12th century
“Brain is mute to X rays”

Moniz

Cerebral angiography on cadavers that were transported on his car.

1896 Teichmann mixture

Lime, mercury, petroleum

1926 Sodium bromide,

70% strontium bromide injected in dogs,
and in one patient that died afterwards

25% sodium iodine

6 patients died on the 9th patient succeeded to demonstrates a pituitary tumor

1927 Starts using thorium diaxide, radioactive compound not popular in US
Moniz cerebral angiogram of a dog strontium bromide

Moniz Showing an Angiogram in Paris Babinski, Sicard and Roussy
1927

Moniz introduced "arterial radiography" with a "cut down" technique

Almeida Lima obtained the access to diagnose tumors
Moniz, coined the terms
Carotid siphon
Sylvian arteries
Carotid Occlusion
arterial, capillary and venous phases
“miracle of Moniz” Walter Freeman, 1936

C. Miller Fisher
“Oclusion of the internal carotid artery”
Arch Neurol Psychiat 63:346-377, 1951
1928 Fuller Allbright convinced Dandy to ligate the ICA in a patient with a III palsy and a pcom aneurysm.

Patient died from Stroke

Walter Dandy reports aneurysm clipping with McKenzie clip.

“Aneurysms could only be cured by clipping, trapping, stuffing with muscle, coagulation or excision”

Pcom, no angiogram, 1st silver clip
1929 Fuller Allbright

“it is to be hoped that, as the diagnosis become more exact, some surgical techniques can be developed to save these group of patients”
1931  Brooks first to occlude CCF internally with muscle embolus

1933  Moniz reports the use of angiography to demonstrate a cerebral aneurysm

1933  Norman Dott, Edinburgh operates the first aneurysm, pcom, demonstrated by "arterial radiography"
1933 Hambly & Gardner describe the physiopatology of *pulsatile exophthalmous*

Treatment of pulsatile exophtalmous
Arch Surg 27:676-685, 1933
1936 Myerson and Loman described the percutaneous puncture

1937 Dandy presents the treatment of CCF, including partial proximal occlusion and distal ligation of the ICA … trapping
Dandy’s treatment of CCF
1940’s Thorostat was considered a dangerous agent, radioactive, responsibly of liver cancer and cirrhosis.

1941 Dyke “the main indication is to determine whether an aneurysm exists or not”

1941 Werner, reported the use of wire, and electricity to thrombose an intracranial aneurysm.
1941  Werner, reported the use of wire, and electricity to thrombose an intracranial aneurysm. Used direct puncture...
1947  Radner reports 221 angiograms including selective catheterization of vertebral arteries

1949  Moniz received the Nobel Prize for his work on frontal leukotomy. Nominated in 1927, 1928 and 1933  
Recommended Dandy for his work on Myelogram and pneumoventriculogram

Hans Christian Jacobaeus, Chairman of Nobel Committee
1951  Seldinger developed the technique of “guide wire”

1960  Luessenhop and Velasquez, successfully advanced a balloon into a carotid supraclinoid aneurysm “endoarterial embolization” with methylmethacrylate particles for aVM’s

2.5, 3.0, 4.0, 4.2 mm spheres
Krayenbuhrl & Yasargil accumulated significant experience in angiography with >10,000 studies (1953-1964)
1964 Gallagher, developed the "piloejector gun", pneumatic deliver of horse hair into the aneurysm
1965 Parkinson, defines the direct exploration of the cavernous sinus

“Parkinson’s triangle”
“The exposure resembled a proctoscopic passage through massive internal hemorrhoids.”

“The neurosurgeon is required to make a rapid excursion through the tightly packed tangle of abnormally dilated, thickened, adherent veins to the underlying arterial wall as he dissects his way to the fistula.”

Dwight Parkinson, 1964
1965 Mullan, Chicago, using stereotactic technique inserted a needle puncturing the aneurysm and passed wires through it. Then administered current 200 – 2000 mA during 1-2 hour periods. Angiograms q30 min to follow the progress …

1 pt worst after 3 required further clipping. Antifibrinolytic therapy to prevent aneurysm re-rupture.
Electrothrombosis
1965 Yasargil was considered an expert in angiography and stereotaxy introduced a *special* technique to Robert Rand and John Alksne (UCLA)

1965 Alksne navigated 3micron diameter carbonyl sphere rubbing a magnet on experimental aneurysms created in dogs

1969 Alksne and Rand published their result with 9 patients, 6 had complete occlusion and 3 had partial occlusion with a stroke
1969 Dotter, describes for peripheral vascular stenosis

“tubular prosthesis within the blood vessel”
Improved the gum for dental impressions,

*internal prosthesis*

“This Stretch out”

*bile duct prosthesis*

66’s Weldon introduced the word to cts “To stent a mitral valve”

Charles T. Stent 1807-1885
“After ligation of the CCA the CCF continues to carry out its draining function, being supplied from the ipsilateral ECA and the Circle of Willis. Consequently, the therapeutic effect achieved with this operation is insignificant.”
1969 Tethered embolus originally described by Arutiunov, Serbinenko, and Shcheglov

Combined with distal ligation, embolization and proximal ligation of cervical ICA
Tethered Embolus

Diagram showing a fistula with labels for clip, muscle, carotid int. a., carotid comm. a., polychlorvinil tube, syringe, and a nylon thread (0.3 mm).
1974

Serbinenko introduced detachable balloons (1959), initially for cavernous aneurysms.

Affected by the *Cold War*

May 1
Temporary occlusion of the cavernous carotid revealed flaws in the Matas’ test.
1978 Debrun reported his results using balloons to treat 14 carotid siphon aneurysms.

8 success, 5 pts had parent vessel preservation, 4 pts died and 2 had stroke.

Temporary ICA occlusion with balloon catheter while injecting through the vertebral artery.

Delineates site of fistula through the filling from posterior communicating artery.
80’s Debrun, Shcheglov (725), Serbinenko (267), Higashida (87), Berenstein balloon occlusion of aneurysms, cavernous sinus aneurysms, CCF’s parent vessel occlusion transient ischemic event aneurysm rupture

Failure to fill the geometry of the aneurysm

unprotected fundus ball valve system parent vessel occlusion
Guido Guglielmi (1947 - )
Inspired by Mullan, Serbinenko, Debrun
Father suffered SAH, pcom
Expert in electricity
Encouraged by Guidetti, Charles Drake & Fernando Viñuela
- Target was initiated by an oncologist to embolize collagen and chemotherapy on liver masses
- Variable stiffness catheter
- Joint efforts with Target Therapeutics Ivan Sepetka
- Target was bought by 1 m in 1987
1990 Guglielmi, invented in Italy detachable coils (GDC) platinum coil that is attached to stainless steel guide that allows to deploy the coil into the aneurysm and electrolytically dissolve the connection between the guide and the coil.

Positive current facilitates thrombosis of the aneurysm attracting negative charged particles (rbc, plt, wbc, fibrin)
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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| 1992 | Guglielmi reported 43 pts posterior fossa aneurysms [JNS; 77:515-524, 1992]  
85% occlusion of small neck  
15% occlusion of wide neck  
5% morbidity  
2.5% mortality |
| 1995 | GDC cleared for market by FDA, 9/95 |

USC  
BNI
1996 Byrne, 50 pts treated with GDC, immediate results and at 6 months (42 pts)

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<th></th>
<th>0</th>
<th>6m</th>
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<tr>
<td>100%</td>
<td>100%</td>
<td>83% small aneurysms</td>
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<tr>
<td>95%</td>
<td></td>
<td>81% large aneurysms</td>
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<tr>
<td>85%</td>
<td></td>
<td>50% giant aneurysms</td>
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J Neuro Neurosur Psych 1995; 59: 616-620

1996 McDougall reports series
33 coiled basilar aneurysms

84% > 90% occlusion at 12m

JNS; 84, 84: 393-9
1997 Viñuela, reports multicentric 403 coiled aneurysms 1990-1995

- 71% Small aneurysms
- 35% Medium
- 50% Large

JNS 1997; 86: 475-82
1997 Moret reports “reconstruction technique” in the treatment of wide neck aneurysms, using non-detachable balloons.

1997 Higashida reports the use of stent assisted coiling

JNS 1997;87:944-9
1997    Boston Scientific buys Target Therapeutics in stock trade worth $2.1 Billion
2002 ISAT

Prospective, randomized, controlled
SAH, Suitable for either ttx, NSG, NR
Coil Vs Clip reduce dead MRS 3-6,
rebleed, qol, cost & effect, epilepsy

43 centers, 2143 pts (2pts in US)
88% in both groups were in good
clinical status WFNS 1-2
90 % aneurysms < 10mm
97 % anterior circulation
follow @ 1 year in 1594 pts
78% excluded from the study

Craniotomy, it was thought the aneurysm was more feasible for being clipped
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<th>Dead or poor RMS</th>
<th>Dead from rebleeding</th>
<th>Rebleed</th>
<th>Occlusion</th>
<th>Seizures</th>
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<tr>
<td><strong>Coil</strong></td>
<td>22.6 %</td>
<td>6.1%</td>
<td>2.4% *</td>
<td>66%</td>
<td>5%</td>
</tr>
<tr>
<td><strong>Clip</strong></td>
<td>30.6 %</td>
<td>6.8%</td>
<td>1.2%</td>
<td>82% **</td>
<td>9%</td>
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* Risk of rebleding 0.2/pt/y (1-8 mean 4y)
** 450 / 1070 had angiogram

Lancet sep 2005
CAVEATS

78% of eligible pts were not randomized!
Just for ruptured aneurysms !!!
Pts that had surgery were treated 2 days later than pts that were coiled

ISAT population is very special, does not match US practice
  Neurosurgeons were general neurosurgeons
    3.5% wrapped, no clipped or partially clipped
  Highly specialized endovascular

No intra or even no postoperative angiogram, “visual estimation”

Applies to this population @ ISAT centers

97.3% Anterior Circulation
90% Good clinical status WFNS 1-2
90% <10mm
Wide necks

Balloon remodeling pioneered by Moret Provides temporary remodeling during the coil deposition
Stent assisted coiling

- Stent reduces aneurysm inflow
  provides buttress for coils

- Rescue for herniated coils

- Stent thrombosis, myointimal proliferation

  Fiorella ajnr, 2004

- Synergism with coated coils
Coated coils

Platinum coil coated with polyglicolide (90%) and polylactid (10%)

Expensive

Hydrogel increases the compaction of the coils within the aneurysm sack
Conformal deployment

ACT MicroCoil, Anatomical
Conformable Three D follows aneurysm geometry and detaches instantaneously
Liquid embolic agents

Balloon assisted and filling of the aneurysm Onyx
Flow Diversion PED
POST-TREATMENT - Lateral DSA/native
6 months f/ u
Acknowledgements
Felipe C Albuquerque, MD
Cameron McDougall, MD
Gregory Lekovic, MD, PhD, JD
Mark Preul, MD
Marie Clarkson
C.J. Mapson