Emerging Surgical Technologies:
Open vs. Endoscopic Craniosynostosis Repair

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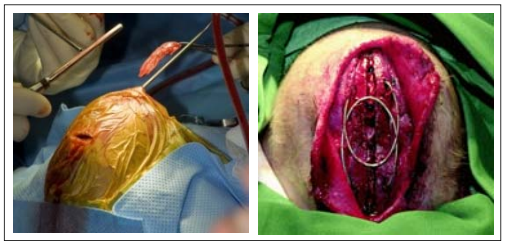


Assistant Professor, Harvard Medical School

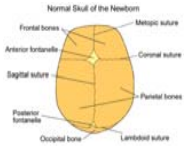
Faculty Disclosure Information

I have no financial relationship with the manufacturer(s) of any commercial product(s) and/or provider(s) of commercial services discussed in this CME activity.

Open vs. Endoscopic Craniosynostosis Repair
Learning Objectives

- Identify different types & etiologies of craniosynostosis repair
- Recognize the evolution in treatment options with the current role of minimal invasive endoscopic surgery
- Compare and contrast anesthesia implications, risks and benefits associated with various treatment options

Open vs. Endoscopic Craniosynostosis Repair



1. Craniosynostosis
Identify different types and etiologies

2. Evolution of Treatment Options
Endoscopic-Assisted Strip Craniectomy (ESC)
Springs for bone expansion

3. Anesthesia implications, Risks, Benefits, Outcomes

1

Historical Perspective - Craniosynostosis

1890 Lannelongue performed the first strip craniectomy; Recommended treatment for nearly 80 years

1970's Extensive cranial remodeling procedures introduced by Tessier and others

1997 Springs were pioneered as a way of dynamic remodeling of the growing infant skull by Claes Lauritzen

1998 Suturectomy was reintroduced by Jimenez and Barone using the endoscope and post-operative orthotic molding

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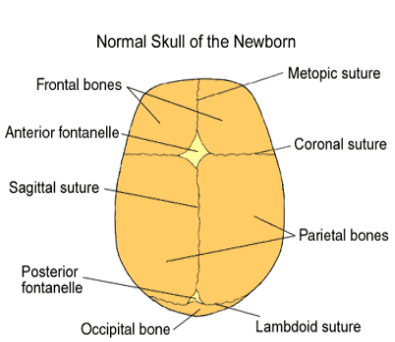
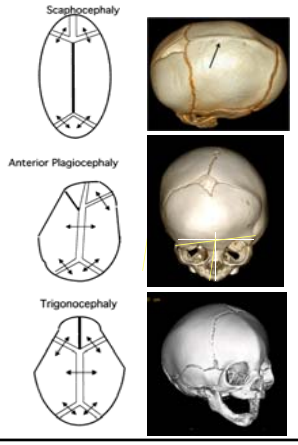
Craniosynostosis is a Congenital Anomaly Premature Fusion of Sutures of Infant Skull





Virchow's law

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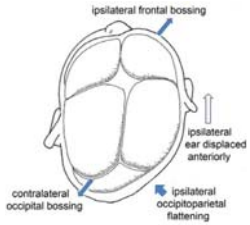
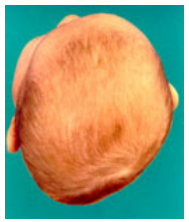
Positional or Deformational Plagiocephaly is Non-Synostotic: The Infant's Skull Deforms as a Result of Prolonged External Force





Risk factors:
- Prematurity
- Torticollis
- Intrauterine constraints
- Back to Sleep Program (AAP 1992)

Treatment:
- Active repositioning < 4 mo/old, supervised "tummy time"
- Physical Therapy, torticollis (2-4 mo/old)
- Helmet Therapy > 5-6 mo/old

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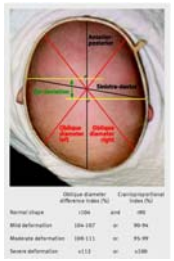
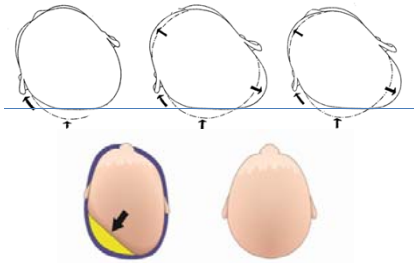
Cranial Orthosis for Deformational Plagiocephaly

- 6 month treatment, non invasive, well tolerated
- Works by providing passive resistance to growth in areas of overgrowth, and shields areas that require growth





- HEADS study: No effect of helmet therapy vs natural course can be shown in infants with moderate to severe positional skull deformation. (Van Wijk RM et al. BMJ 2014)

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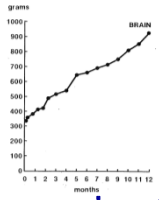
Cycle of Craniosynostosis Surgery

1890 – Lannelongue and Lane

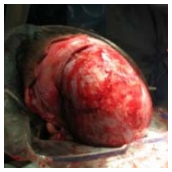
2000 - Endoscope, cranial orthoses



1980-90's - John Shillito: Plea for early operation

Strip craniectomy

Inadequate cosmetic results



cranial remodeling operations

1970's - extensive cranial remodeling procedures.

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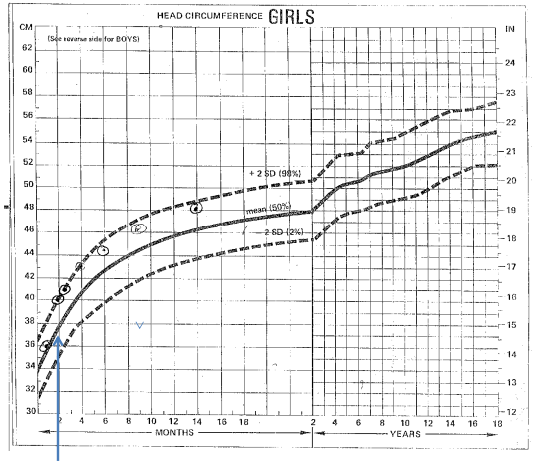
Head Growth



Surgery

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The Current Trend Towards Minimally Invasive ESC is Philosophically Different From Prior Strip Craniectomy Procedures.

- **Open Surgery**
  - Mechanical operation in which bones are removed and replaced into desired position
  - Anesthesia implications:
    - Massive blood loss
    - Venous air embolism
    - Airway complications
    - ICU, extensive hospitalization
- **Minimally Invasive ESC**
  - Suture release procedure
    - Depends on brain growth to move bones
    - Uses a helmet to direct growth
    - Conceptually turns synostosis into a deformational problem

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Comparison of Operative Techniques

Procedure	Surgical time (min)	Blood loss (% of EBV)	Blood transfusion % of patients	Hospital stay days
Strip craniectomy	45-145 (72)	25%	40%	3.8
π Procedure	45-185 (83)	60%	100%	3-5
Calvarial vault remodeling	100-390 (360)	≥ 100%	100%	4 - 5
Endoscopic strip craniectomy	31-95 (54)	7%	5-10%	1-2

Maugans TA et al. Pediatr Neurosurg 1997; Boop FA et al. J Neurosurg 1996; Burstein FD et al. J Craniofac Surg 1994; Stricker PA et al. Pediatric Anesthesia 2010; Jimenez DF et al. Pediatrics 2002;

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Early Treatment of Craniosynostosis with ESC is an Efficacious, and Valuable Therapeutic Alternative to the Current Extensive Surgical Treatment Modalities

Compared to open procedures (N=100):

- ↓ Surg. time (mean 53 min)
- ↓ EBL (mean 26 mL)
- ↓ PRBC (intraop *N* = 1; postop *N* = 10)
- ↓ Hospital stay (mean 1 day)
- ↓ Hospitalization costs

Jimenez, DF et al. Pediatrics 2002; 110; 97-104

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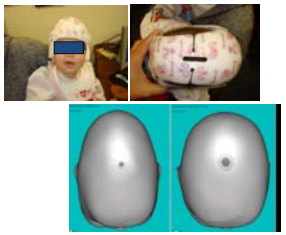
ESC and Orthoses in Infants ± 3 Months Old (Range 1- 6 Months)

- Supine or modified prone position
- 1 – 1.5 cm incisions -> subperiosteal dissection, burr-hole
- Rigid endoscope - emissary veins
- 1 cm strip of suture removed



- Orthotic critical to outcome:
  - Start within a week after procedure
  - 22-23 hours/day for 6 - 12 months
  - Conceptually this becomes treatment of congenital deformation

11 Berry-Candelario et al. Neurosurg Focus 2011

Surgical Steps: Endoscopic Sagittal Strip Craniectomy

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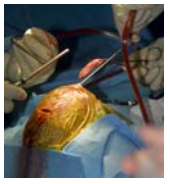
Surgical Steps: Endoscopic Sagittal Strip Craniectomy





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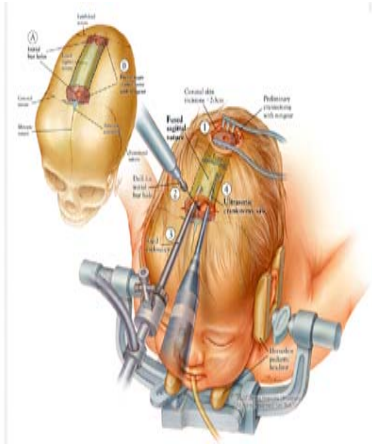
Novel Use of an Ultrasonic Bone-Cutting Device for ESC



- Based on ultrasonic oscillations, hard tissue or bone is cut and soft tissue is spared.
- Coagulation of the bone decreases bone bleeding
- Potential complication: unintended durotomy

14 Chaichana, KL et al. Childs Nerv Syst. 2013

Note of Caution: Positioning for Sagittal ESC

- Prone position with extended head and endotracheal tube placement
- Surgical field above heart level

Johnson, JO et al. Paediatric Anaesthesia 2002

Meier, PM et al. Anesth Analg 2011

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Minimally Invasive ESC Leads to Change in Perioperative Management

- Risk factors PRBC (8%)
  - Weight ≤ 5 kg
  - Syndrome
  - Learning Curve
- Risk factors ICU (8%)
  - PRBC transfusion
  - Resp. complications

- Change of anesthesia practice
  - No A-line in healthy infants
  - 2 large bore intravenous lines
  - PRBC available in OR
  - LA 0.5 mL/kg bupi 0.25% + Epi 1:200000
  - Doppler monitoring for VAE

Meier, PM et al. Anesth Analg 2011

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Incidence of VAE is Significantly Reduced During ESC vs Open Reconstruction Procedures

	% of Venous Air Embolism	
	Doppler	TTE
Open Surgery	83 %	66 %
Endoscopic	2 – 8 %	-

(Harris et al. Anesthesiology 1987; Faberowski et al. Anesthesiology 2000; Meier et al. A&A 2011; Tobias et al. Anesthesiology 2001)

- Possible increased risk
  - ESC with single incision (metopic, coronal)
  - Aerosolized fibrin sealant application under pressure (Felema et al. Ped Anesthesia 2013)

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Total Costs for Sagittal ESC Averaged ≈ 40-60% of the Costs for Open Reconstruction Surgery.

	CVR	ESC
Abbott et al 2012* Median, (range)	$ 55,121 (44,690 – 86,313)	$ 23,377 (20,987 – 24.977)
Chan et al 2013 Mean, (range)	$ 63,424 (23,082 – 373,626)	$ 24,404 (17,899 – 34,166)
Vogel et al 2014 Mean, (range not available)	$ 56,990	$ 37,255

Abbott, MM et al. J Craniofacial Surg 2012
*no difference in median CI preop and postop (follow up median 4.2 vs 22.2 months)
Chan, JWH et al. J Craniofac Surg 2013
Vogel, TW et al. J Neurosurg Pediatrics 2014

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Evolving Role of Springs in Craniofacial Surgery: A Way of Remodeling the Growing Infant Skull Postop.

Lauritzen, C et al. Plast Reconstr Surg 2008

- **Indication:**
  - sagittal, metopic, bicoronal, multiple synostosis,
  - midface surgery
- **N=100, age: 2.5 months – 12 y**
- **No major complications**
  - Spring dislodgement 5%
  - Difficult removal 5%
  - Further surgery 5%
- **Spring removal 7 months postoperatively (sag. synostosis)**
- **Data compared favorably with standard craniofacial procedures.** (Windh,P et al 2008)

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Springs: A Technique for Cranial Bone Expansion

- **Spring insertion**
  - Midline lazy-S scalp incision,
  - Midline 1 cm strip craniectomy osteotomy including the sagittal suture
  - Insertion of 1.2 mm stainless steel omega shaped springs
- **Spring removal**
  - Approximately 4-6 months later
  - Two or three small incisions

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Spring Assisted Cranial Expansion vs CVR for Sagittal Craniosynostosis: Changes in Anesthesia Management

	SAS Insertion (n=100)	SAS Removal (n=100)	CVR (n=8)
Age (months)	4.4 (2.4-9)	9.0 (6-14)	9.8 (5-14.5)
Weight (kg)	6.2 (5-7)	8.8 (7-10)	9 (8-9.9)
Estimated blood loss (ml)	15.5 ± 12.7	7 ± 2.5	291 (230-352)
HCT preop (%)	34.9 ± 2.9	33.5 ± 4 (n=13)	32 (27-36)
HCT POD1 (%)	27.5 ± 3.4	31.0 ± 4 (n=13)	34 (31-37)
Crystalloid (mL)	158 ± 65	139 ± 67	400 (242-558)
5% Albumin (ml)	42 ± 20 (n=7)	0	N/A
Blood products (n)	0	0	8 (100%)
Surgery time (min)	31.4 ± 8.2	19.2 ± 9.5	3h 25 min
Anesthesia time (min)	103.9 ± 31.6	72.1 ± 25	4h 24 min
Length of stay (h)	34.9 ± 15.11	16.6 ± 7.9	4.1 d (3.8-4.4)

Riri DG et al Anesth Analg 2003; Ririe DG et al. Pediatric Anesthesia 2011;

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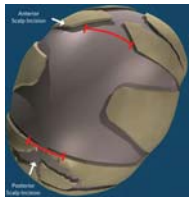
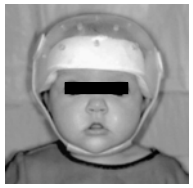
Follow-Up Results For Sagittal ESC and Helmet Therapy: Improvement of Cranial Index





- **Sagittal ESC (N=139)**
  - Wide vertex craniectomy (width mean 5.4 cm, range 1.5-8 cm), bitemporal / biparietal barrel stave osteotomies, postoperative helmet molding therapy for 1 year
- **Follow-up (mean 39 months)**

  Improvement of Cranial Index from preop 67.6
  - 87% of patients CI > 75,
  - 8.7% of patients CI = 70-75
  - 4.3% of patients CI < 70

Jimenez DF et al. J Neurosurg Pediatrics, 2004; Jimenez DF et al. Childs Nerv Syst , 2012
Jimenez DF et al. Atlas Oral Maxillofacial Surg Clin N AM 2010

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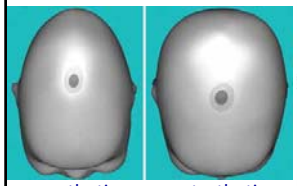
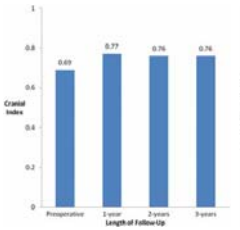
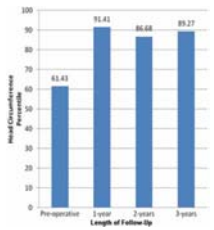
Sagittal ESC and Helmet Therapy: Improvements in Cranial Index (CI) and Head Circumference Percentile are Comparable to Open Remodeling Procedures and Maintained over 2 Year Follow-up (N=56)



preorthotic postorthotic





Laser scanning report:
Cranial Index (ratio width/length) improved from 0.72 to 0.83

Cranial Index:
Preop CI mean improved from 0.69±0.04 to 0.76±0.04

Head Circumference:
Preop percentile mean improved from 61±34% % to 89±17%

Ridgeway EB et al. J Neurosurg Pediarics 2011

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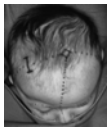
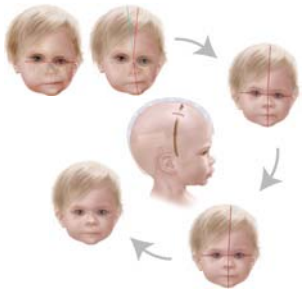
Early Treatment of Unilateral Coronal Synostosis with ESC and Orthosis: 16 – Year Experience





- **Coronal ESC (N=115)**
  - Craniectomy (width mean 0.6 cm, range 0.3-2cm), postop helmet molding therapy for 10-12 months
- **Follow up (mean 7.7 years)**
  - Vertical dystopia correction of more than 80% from baseline in 2/3 of patients
  - Nasal & sagittal craniofacial deviation correction of more than 80% was achieved in 80% of patients
  - Supraorbital rim advancement of ipsilateral eye was obtained in 98% of cases

Jimenez DF et al J Neurosurg Pediatrics, 2013

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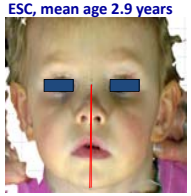
Early Unilateral Coronal ESC and Orthosis Results in Better Overall Facial Symmetry and Comparable Brow Symmetry than FOA in Later Infancy

FOA, mean age 3.8 years; ESC, mean age 2.9 years



FOA, mean age 3.8 years; ESC, mean age 2.9 years

Measurement	FOA Mean ± SD	ESC + Helmet Mean ± SD	Two-Sample t-Test P
Brow Symmetry	1.0 ± 0.6	1.7 ± 0.9	P=0.054
Midline Deviation	3.6 ± 2.4	1.4 ± 1.1	**P=0.018**
Nasal Tip Deviation	5.6 ± 3.0	2.3 ± 1.8	**P=0.006**

Tan SPK et al. J Craniofac Surg 2013

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Neosuture Formation and/or Persistent Craniectomy Gap after ESC and Helmet Therapy is Common and appears to correlate with better phenotypic outcome

- Retrospective study (N=17)
- Helmet therapy may reduce the incidence of re-fusion after ESC by accelerating growth along the craniectomy site and altering dural signaling
- Bony re-fusion (N=2) appears to be correlated with poor phenotypic improvement

Sauerhammer TM et al. Plast Reconstr Surg 2014

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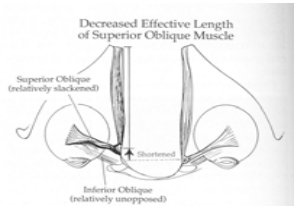
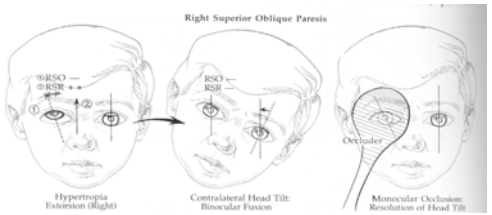
Relationship Between Unilateral Coronal Synostosis, Strabismus, and Ocular Torticollis





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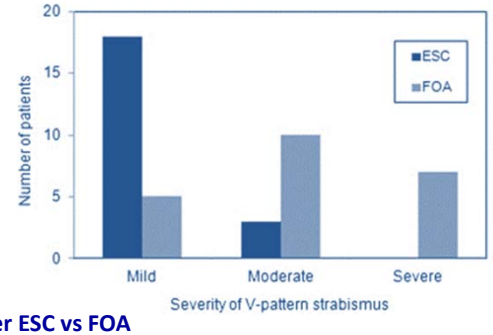
Gosain AK et al. Plast Reconstr Surg 1996

2-Year Follow-Up: Ophthalmologic Outcomes Better after ESC/Orthosis than Fronto–Orbital Advancement



After ESC vs FOA

- Less severe pattern of strabismus (P<0.0001)
- Less need for strabismus surgery : Odds ratio FOA vs ESC 6.3:1 (95 % CI 1.09-69.34) ESC 2/21; FOA 9/22; P= 0.03
- Less extremes of astigmatism with ESC

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MacKinnon S et al. J AAPOS 2013

Endoscopic strip craniectomy: Summary

- ESC is effective in reducing
  - PRBC transfusion (7-10%)
  - VAE (2-8%)
  - ICU admission (8%)
  - Hospitalization (discharge POD 1) and costs
- Sagittal ESC comparable to open reconstruction
  - Cranial index, head circumference
- Early unilateral coronal ESC vs later FOA
  - Better overall facial symmetry
  - Less severe ocular pathology, fewer strabismus surgeries
- Limitations:
  - Lack of standardized outcome measures
  - Small sample size, single center studies
  - No long-term outcome studies

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Conclusions

- New technologies have markedly altered treatment paradigms for craniosynostosis
- Depending on the patient's age and wishes of the family, both minimally invasive releases of the fused suture or complete reconstruction of the skull are possible
- The benefits and drawbacks of each procedure should be considered and discussed with family

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Thank you!