A Comprehensive Guide to Pediatric Anesthesia

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Abstract

It was hypothesized that a comprehensive pediatric guide to the operating room in conjunction with a PowerPoint presentation would increase the knowledge base of twenty-six Adventist University of Health Science nurse anesthesia junior students. The perceived outcome of the increased knowledge would be a reduction in pediatric adverse events through the use of this comprehensive guide. Studies have shown that standardization and resources can reduce peri-operative adverse events. A pediatric guide to the operating room was formulated as well as a PowerPoint presentation that reflected the pediatric guides content. Participation in the pretest and posttest evaluation was voluntary and all students were randomly assigned a number to de-identify the data. A pretest and posttest were administered to evaluate the knowledge retention after the presentation. For statistical analysis, a paired sample t-test was performed to analyze the mean score before and after receiving the lecture. Statistical analysis was performed by Roy Lukman, PhD. The mean pre-test score was 36.9231 while the mean post-test score was 68.4615 with a confidence interval of 95% , a t-value of -8.806, and a p value < 0.05; therefore, it can be concluded that the average scores increased significantly and the results were significant.

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Problem

JLR Medical Group is one of the largest anesthesia groups in the country, consisting of more than 70 anesthesiologists and 160 nurse anesthetists. These numbers do not include the potential 40-50 student registered nurse anesthetists (SRNA's) that may be rotating at any given time. Together, they provide over 100,000 anesthetics per year (JLR Medical Group, n.d.). Along with a group this size comes a tremendous necessity to have numerous adequately trained anesthesia providers in the specialty of pediatrics. However, it is impossible to avoid turnover, and with a group this size, one-on-one training can become cumbersome and cost-ineffective, if not impossible. Therefore, there is a need for a comprehensive guide that can augment the training that our anesthesia providers have incurred at other facilities and tailor it to the needs of the pediatric anesthesia provider at facilities to which JLR Medical Group provides services.

There have been multiple studies published that indicate the pediatric population undergoing anesthesia has an increased risk of perioperative adverse events related to cardiac and pulmonary complications (Schleelein, 2016). Inadequate anesthesia training or knowledge may be significant contributors to these events (Wacker & Kolbe, 2016). As a result, a pediatric anesthesia guide was created that serves to address common areas of deficiency; furthermore, this comprehensive guide to the pediatric anesthesia environment will give the practitioner more confidence as they provide anesthesia to this unique patient population and improve the knowledge of the practitioner or anyone who utilizes this guide.

Although the Adventist University of Health Sciences (ADU) Nurse Anesthesia Program (NAP) provides students with a four-week pediatric clinical rotation and eight weeks of pediatric didactic, it is likely insufficient to render him or her competent to provide anesthesia to the entire

spectrum of pediatric patients that are encountered each day. In addition, depending on the timing of said clinical rotation, the student may not have completed the course prior to beginning the rotation. This further strengthens the notion that the comprehensive guide to pediatric anesthesia at JLR medical group is essential to anesthesia providers at all stages of their career or training.

Literature Review

The literature for pediatric perioperative anesthesia is limited; however, the evidence points toward increased risks of cardiac and pulmonary adverse events (Bhananker et al., 2007). Beecher and Todd (1954) conducted one of the first studies to look at the pediatric population and their increased risk; however, there is a lack of current literature available. Checklists and guides can improve the outcome in patients if utilized properly and consistently (Hagerman, Varughese, & Kurt, 2014). Perioperative adverse events can have detrimental consequences in the pediatric population; moreover, risk prediction tools and guides prove useful in outcomes (Subramanyam, Hossain, Anneken & Varughese, 2016). The sequelae of respiratory events in the pediatric population can be of greater concern and lead to increased hospital costs and length of stay (Subramanyam, Hossain, Anneken & Varughese, 2016). Respiratory induced cardiac arrest accounts for approximately 50% of cardiac arrest in children (Salem, Bennett, Schweiss, Baraka, Dalal, Collins, 1975). If the risk of perioperative cardiac and pulmonary adverse events is higher in children with a proportion of this attributed to the failure to ventilate, it seems pertinent to increase the knowledge base of the user (Keenan and Boyan, 1985).

The child undergoing surgery goes through a sequence of events which differ significantly from the adult in terms of health care delivery, attitudes, volume and procedure types, as well as perioperative risks. The overall risk of perioperative death in children is low;

however, the risk of perioperative adverse events is relatively high (O'Leary, Wijeysundera, & Crawford, 2016). A majority of the preventable adverse events occur in the operating room; moreover, the provider should be equipped with as much knowledge as possible in efforts to mitigate these errors (O'Leary et al., 2016). There have been a number of studies which aimed to evaluate the effectiveness of surgical safety checklists as they relate to perioperative outcomes and adverse events; in fact, the World Health Organization developed a surgical safety checklist with the goal of reducing morbidity and mortality surrounding the operating room. The surgical safety checklist has now become a standard of care, but there is a lack of literature as it pertains to operating room resources for the anesthesia provider. The widespread implementation of surgical safety checklists has led to multiple studies and allocated resources. The goal of the pediatric operating room guide is the utilization as a reference and in essence a checklist of pertinent components needed for that surgery.

One of the most pertinent articles pertaining to our comprehensive guide was a study conducted by O'Leary, Wijeysundera, and Crawford who hypothesized that the number of children admitted to the hospital for surgery who had perioperative adverse outcomes would decrease after mandated implementation of surgical safety checklists in Ontario. The primary goal of their study was to evaluate whether or not surgical safety checklists improved outcomes in children who underwent common pediatric surgeries. O'Leary et al., also evaluated whether or not the use of standardization and resources could reduce health care utilization such as length of stay, unplanned returns to the operating room, and visits to the emergency department. The study by O'Leary et al. was conducted via retrospective analysis and looked at children greater than 28 days of life and less than 18 years of age who had been admitted before and after the mandated implementation of the surgical safety checklist. O'Leary et al. determined mortality and

complication rates for each surgery and through a combination of multivariable logistic regression they determined the overall rate of complications did not change; however, they did note that the implementation and standardization of care does seem to affect the outcomes in many settings, just not this particular one.

There are many studies that show the use of surgical checklists and standardization improve patient outcomes. Treadwell, Lucas, and Tsou analyzed 33 studies and found that surgical checklists were associated with detection of potential hazards, reduction in surgical complications, and an increase in communication among operating room staff. The authors did not specify the degree to which checklists and standardization improve outcomes; however, their overall conclusion was that they were effective. As part of their analysis, Treadwell, Lucas, and Tsou studied the implementation of the WHO surgical safety checklist at eight varying sites throughout the world. The sites varied greatly with differences such as acuity of patients, number of beds, rural versus tertiary as well as complexity of the procedure. Treadwell, et al. collected baseline data 3 months prior to the implementation of the surgical safety checklist and then looked at complications 3 to 6 months after implementation. Statistical analysis was significant and showed a reduction in mortality by almost 50% and a reduction in inpatient complications by 30%. In addition, the authors found that the performance rates for six specific safety indicators also increased after the checklist was introduced, possibly leading to the reduction in complications. Although there is conflicting literature on the usefulness of standardization and resource guides to improve the outcomes of patients, it is believed that the comprehensive guide to the pediatric operating room can help attenuate knowledge deficiencies that could lead to adverse outcomes.

Project Description

The pediatric guide is not meant to be a surgical manual but rather a brief refresher when it comes to pediatric surgical procedures. The primary goal is to increase knowledge of the anesthetic and perioperative implications for common pediatric surgeries. A variety of methods were used including lecturing, powerpoint presentations, and pediatric baseline assessments to address the problem of knowledge deficiency.

The pediatric guide is organized by anatomical sections of the body, these sections include urologic, general surgery, ENT, orthopedic, and congenital cardiac procedures. The congenital cardiac section includes general pearls and basic classification of congenital heart disease as well. The guide includes pediatric medications such as resuscitation, vasoactive, neuromuscular, reversal, induction, sedatives, analgesics, antiemetics, and intravenous antibiotics. The anatomic organization of the guide is useful as many providers work with one surgeon in a specified room; moreover, the guide will most likely include all of the surgeries being performed in that room for the day. The transition from one similar surgery to the next will be easy and require little searching on the reader's part.

The clinical pearl section of the guide provides information such as endotracheal and laryngeal mask airway sizes based on weight. The clinical pearl section has additional resources such as anatomic and physiologic differences within the pediatric population, the main sections covered include pediatric airway anatomy, respiratory physiology, cardiac physiology, hemodynamic changes at birth, and the transition from fetal to neonatal circulation.

The guide was created using not only a host of online resources but utilizing surgical and anesthesia manuals for surgical descriptions and required needs for specific surgeries. Pediatric

Anesthesiologists and Certified Registered Nurse Anesthetists overlooked the guide and provided additional input based on their personal history with the surgeries described.

A presentation created in Microsoft PowerPoint of 42 slides was presented to the Nurse Anesthesia Program cohort of 2018 in their Clinical Conference II class (MSNA 502). The powerpoint was created based on the information in the pediatric guide. The pediatric guide was referenced to create pertinent bullet points and brief descriptions which followed the same categorization as the guide provided. As the material was presented, the lecturers expanded upon the powerpoint and incorporated personal experiences that they had with these surgeries to help the junior students connect with the material. The junior class was allowed to ask as many questions as needed and the lecturers provided additional clarification on topics that traditionally are harder to comprehend such as congenital cardiac anomalies and procedures.

The cohort included 26 students. The presentation took place in a classroom at Adventist University of Health Sciences. Informed consent was explained to the 2018 NAP cohort and obtained before a baseline assessment of their pediatric knowledge was acquired (see Appendix A and B). The baseline assessment test (pretest) was created based on the information presented in our powerpoint; however, the questions were carefully chosen as the content represents common areas that are tested on the national board certification for registered nurse anesthetists. After the PowerPoint presentation, a posttest was administered including the same baseline assessment previously administered. No names were included on the tests administered and all data was de-identified; however, numbers were utilized to match pretest and posttest assessments. The data was entered into Microsoft Excel using a basic spreadsheet and sent to Roy Lukman for statistical analysis.

Evaluation

It was hypothesized that utilizing a pediatric guide to anesthesia increased the pediatric knowledge base of student nurse anesthetists at Adventist University of Health Sciences after receiving a lecture on the pediatric guide and performing a pretest and posttest assessment; moreover, the hypothesis was correct. The study conducted and implemented was a quantitative design. The subject sample was selected for convenience and the material was presented to 26 students enrolled in the 2018 NAP cohort at ADU via a PowerPoint presentation in their Clinical Conference II class (MSNA 502) on February 6, 2017. Inclusion criteria included students currently enrolled in the 2018 NAP cohort at the time of the presentation. Students received a test consisting of ten questions prior to the lecture to gain a baseline assessment of knowledge regarding anesthesia as it pertains to the pediatric population. After completion of the PowerPoint lecture, the students re-took the same exam. For statistical analysis, a paired sample t-test was performed to analyze the mean score before and after receiving the lecture. Statistical analysis was performed by Roy Lukman, PhD. The mean pre-test score was 36.9231 while the mean post-test score was 68.4615 with a confidence interval of 95% , a t-value of -8.806, and a p value < 0.05; therefore, it can be concluded that the average scores increased significantly and the results were significant.

Limits to the evaluation process include the lack of capabilities to examine long term effects of the increased knowledge base; moreover, knowledge retention and clinical application. The process included short term evaluation of knowledge retention with generalization to standardization of care in the operating room, the authors recognize these are associations and

have no direct casual effects. The authors also recognize the need for additional studies in the area of pediatric standardization of care in the operating room as it relates to resources guides.

Results and Conclusions

The results from the creation of the guide have led to the conclusion that utilizing a PowerPoint guided lecture can increase the baseline knowledge of student nurse anesthesia students. The mean score on the baseline assessment improved substantially. Upon conducting the literature review it was found that a lack of standardization of care has led to increased preventable errors. Using a guide or reference can improve knowledge; moreover, it may decrease the amount of errors due to knowledge deficiency. If anesthesia providers are diligent and use this comprehensive guide to remind them of common co-morbidities, anesthetic implications and additional tips for the cases being performed that day, this guide can possibly change outcomes in the operating room.

As previously stated, there is conflicting literature on the usefulness of checklists on outcomes surrounding the peri-operative period; therefore, it cannot be concluded with certainty that the guide will improve outcomes. It can be concluded that PowerPoint guided lectures effectively increase the knowledge base of nurse anesthesia students. In addition, there is substantial literature to suggest that standardization of care will decrease pediatric peri-operative adverse events. Literature also suggests that the rate of adverse events in the pediatric population is significantly higher with the reasons being multifactorial; however, there are components consistent with knowledge deficiency. If a resource guide can attenuate the knowledge deficiency surrounding the pediatric population and the operating room then the study is a success no matter what metrics are used for analysis.

References

Aspelund, G., & Langer, J. C. (2007). Current management of hypertrophic pyloric stenosis. *Seminars in Pediatric Surgery*, *16*(1), 27-33. http://dx.doi.org/10.1053/j.sempedsurg.2006.10.004

Beecher, H. P., & Todd, D. P. (1954). A study of the deaths associated with anesthesia and surgery. *Annals of Surgery*, *140*, 2-34.

Bhananker, S. M., Ramamoorthy, C., Geiduschek, J. M., Posner, K. L., Domino, K. B., Haberkern, C. M., … Morray, J. P. (2007). Anesthesia-related cardiac arrest in children: Update from the pediatric perioperative cardiac arrest registry. *Anesthesia & Analgesia*, *105*(2), 344-350. http://dx.doi: 10.1213/01.ane.0000268712.00756.dd

Faraoni, D., & Goobie, S. M. (2014). The efficacy of antifibrinolytic drugs in children undergoing noncardiac surgery: a systematic review of the literature. Anesthesia and Analgesia, 118(3), 628-36. http://dx.doi.org/10.1213/ANE.0000000000000080

Gewillig, M. (2005). The Fontan Circulation. Heart, 91(6), 839-846. http://dx.doi.org/10.1136/hrt.2004.051789

Graziano, J. N. (2005). Cardiac anomalies in patients with congenital diaphragmatic hernia and their prognosis: a report from the Congenital Diaphragmatic Hernia Study Group. Journal of Pediatric Surgery, 40(6), 1045-9. Retrieved from http://dx.doi.org/10.1016/j.jpedsurg.2005.03.025

Hagerman, N. S., Varughese, A. M., & Kurt, C. D. (2014). Quality and safety in pediatric anesthesia: how can guidelines, checklists, and initiatives improve the outcome? *Current Opinions in Anesthesiology*, *27*(3), 323-329. http://dx.doi.org/10.1097/ACO.0000000000000078

Isolated Pierre Robin sequence. (2016, July 16). Retrieved from https://ghr.nlm.nih.gov/condition/isolated-pierre-robin-sequence

JLR Medical Group. (n.d.). www.jlrmedicalgroup.com

Landsman, I. S., Wekhaven, J. A., & Motoyama, E. K. (2011). Anesthesia for pediatric otorhinolaryngologic surgery. In Smith's Anesthesia for Infants and Children (8th ed.). Philadelphia: Elsevier.

O'Leary, J. D., Wijeysundera, D. N., & Crawford, M. W. (2016). Effect of surgical safety checklists on pediatric surgical complications in Ontario. *Canadian Medical Association Journal*, *188*(9), E191-E198. Retrieved from DOI:10.1503/cmaj.151333

Rackow, H., Salinitre, E., & Green, L. (1961). Frequency of cardiac arrest associated with anesthesia in infants and children. *Pediatrics*, *28*, 697-704.

Salem, M., Bennett, E., Schweiss, J., Baraka, A., Dallas, F., & Collins, V. (1975). Cardiac arrest related to anesthesia: Contributing factors in infants and children. *Journal of the American Medical Association*, *233*, 238-41.

Schleelein, L. E., Vincent, A. M., Jawad, A. F., Pruitt, E. Y., Kreher, G. D., Rehman, M. A., … Cook-Sather, S. D. (2016). Pediatric perioperative adverse events requiring rapid response: a retrospective case-control study. *Pediatric Anesthesia*, *26*(7), 734-741. http://dx.doi.org/10.1111/pan.12922

Subramanyam, R., Yeramaneni, S., Hossain, M. M., Anneken, A. M., & Varughese, A. M. (2016). Perioperative respiratory adverse events in pediatric ambulatory anesthesia. *Anesthesia & Analgesia*, *122*(5), 1578-1585. http://dx.doi.org/10.1213/ane.0000000000001216

The American Academy of Pediatrics. (2015). Critical elements for the pediatric perioperative anesthesia environment. *PEDIATRICS*, *136*(6), 1200-1206. http://dx.doi.org/10.1542/peds.2015-3595

Treadwell, J. R., Lucas, S., & Tsou, A. Y. (2014). Surgical checklists: a systematic review of impacts and implementation. *British Medical Journal of Quality and Safety*, *23*, 299-318. doi:10.1136/bmjqs-2012-001797

Tsiligiannis, T., & Grivas, T. (2012). Pulmonary function in children with idiopathic scoliosis. *Scoliosis*, *23*(7). doi: 10.1186/1748-7161-7-7

Wacker, J., & Kolbe, M. (2016). The challenge of learning from perioperative patient harm. Trends in Anaesthesia and Critical Care, 7(8), 5-10. Retrieved from http://dx.doi.org/10.1016/j.tacc.2016.03.003

Welborn, L. G., De Soto, H., Hannallah, R. S., Fink, R., Ruttimann, U. E., & Boeckx, R. (1988). The use of caffeine in the control of post-anesthetic apnea in former premature infants. *Anesthesiology*, *68*(5), 796-798.

Yuki, K., Casta, A., & Uezono, S. (2011). Anesthetic management of noncardiac surgery for patients with single ventricle physiology. *Journal of Anesthesiology*, *25*(2), 247-256.

Appendix A

ADU NAP CAPSTONE PROJECT – INFORMED CONSENT

Our names are Collin Radcliffe and Jeremy Jones; we are MSNA students in the Nurse Anesthesia Program (NAP) at Adventist University of Health Sciences (ADU). We are doing a Capstone Project called *A Comprehensive Guide to the Pediatric Operating Room.* This project is being supervised by Sarah Snell and Alescia Devasher. We would like to invite you to participate in this project. The main purpose of this form is to provide information about the project so you can make a decision about whether you want to participate.

WHAT IS THE PROJECT ABOUT?

The purpose of this project is to increase the knowledge base of the pediatric operating room environment.

WHAT DOES PARTICIPATION IN THIS PROJECT INVOLVE?

If you decide to participate in this project, you will be asked to complete an anonymous pre-assessment, attend a classroom presentation, and then complete an anonymous post-assessment. The assessment will address common misconceptions and deficient knowledge related to the pediatric perioperative period. Your participation by attendance at the presentation and completion of the survey is anticipated to take approximately _2 hours.

WHY ARE YOU BEING ASKED TO PARTICIPATE?

You have been invited to participate as part of a convenience sample of students currently enrolled in the ADU NAP. Participation in this project is voluntary. If you choose not to participate or to withdraw from the project, you may do so at any time.

WHAT ARE THE RISKS INVOLVED IN THIS PROJECT?

Although no project is completely risk-free, we don't anticipate that you will be harmed or distressed by participating in this project.

ARE THERE ANY BENEFITS TO PARTICIPATION?

We don't expect any direct benefits to you from participation in this project. The possible indirect benefits of participation in the project is the opportunity to gain additional knowledge about the pediatric operating room environment.

HOW WILL THE INVESTIGATORS PROTECT PARTICIPANTS' CONFIDENTIALITY?

The results of the project will be published, but your name or identity will not be revealed. To maintain confidentiality of assessments, the investigators will conduct this project in such a way to ensure that information is submitted without participants' identification. Investigation will involve de-identified data. Thus, the investigators will not have access to any participants' identities.

WILL IT COST ANYTHING OR WILL I GET PAID TO PARTICIPATE IN THE PROJECT?

Your participation will cost approximately 2 hours of your time, but will require no monetary cost on your part. You will not be paid to participate.

VOLUNTARY CONSENT

By signing this form, you are saying that you have read this form, you understand the risks and benefits of this project, and you know what you are being asked to do. The investigators will be happy to answer any questions you have about the project. If you have any questions, please feel free to contact Collin Radcliffe or Jeremy Jones at Collin.radcliffe@my.adu.edu or Jeremy.jones@my.adu.edu. If you have concerns about the project process or the investigators, please contact the Nurse Anesthesia Program at (407) 303-9331.

_____ _____

Participant Signature **Date**

_____

Participant Name (PRINTED LEGIBLY)

Appendix B

Questionnaire

1. What is the narrowest portion of the pediatric airway?
    a. Thyroid Cartilage
    b. Glottis
    c. Cricoid Cartilage
    d. Hyoid Bone

2. Which statement best identifies the nurse anesthetists understanding of pediatric cardiac physiology?
    a. The infant has very high ventricular compliance
    b. The infant has a very mature SNS making them very responsive to Beta agonists
    c. Infants have decreased ventricular compliance making them very dependent on HR to maintain cardiac output
    d. None of the above

3. Which of the following is commonly associated with tracheoesophageal fistula (TEF)?
    a. VACTERL association
    b. Retinopathy
    c. Extremely high tolerance to volatile anesthetics
    d. TEF is usually an isolated anomaly and these children are otherwise healthy

4. Which of the following statements is correct regarding pyloromyotomy?
    a. Suctioning an in-situ NGT is not sufficient to empty the stomach and a new OGT should be placed and suctioned thoroughly prior to induction of anesthesia
    b. Pyloromyotomy is a surgical emergency
    c. Kids with pyloric stenosis present with dehydration and acid/base disturbances
    d. A&C are correct

5. Which statement would best explain why children presenting for tonsillectomy and/or adenoidectomy might be particularly sensitive to opioids?
    a. These children are usually born prematurely and have less mu opioid receptors
    b. These children often have obstructive sleep apnea with nocturnal desaturation resulting in an up-regulation of the gene responsible for control of opioid receptors
    c. They are not any more sensitive to opioids than any other pediatric patient
    d. They have up-regulation of the MC1R gene

6. Tetralogy of Fallot consists of what defects?
    a. RVOTO, RVH, Overriding Aorta, VSD
    b. Pulmonary Stenosis, RVH, VSD, ASD
    c. Pulmonary Stenosis, RVH, Overriding Aorta, ASD
    d. Pulmonary Stenosis, RVH, Overriding Aorta, RVOTO

7. What are the two requirements before a Norwood can be performed?
    a. Viable aorta, adequate RV contractility
    b. PDA, partially restrictive VSD
    c. PDA, nonrestrictive ASD
    d. Adequate mixing at the ventricular level, PDA
    e. There are no specific requirements

8. One of the primary goals after a Bi-Directional Glenn should be?
    a. Normocapnea
    b. Mixed venous saturation approaching 60%
    c. Spontaneous respirations
    d. Tight control of lactic acidosis
    e. Limiting pulmonary blood flow as to not overcirculate the lungs
    f. There are no specific goals after a Glenn besides normal hemodynamics

9. The Qp/Qs after a Fontan procedure should theoretically be?
    a. 0.5:1
    b. 1:0.5
    c. 1:2
    d. 2:1
    e. 1:1
    f. 1:1.5

10. Interventions for a “TET” spell could include?
    a. Phenylephrine 0.5-1 mcg/kg
    b. Morphine 0.1mg/kg
    c. Oxygenation with AIR
    d. IV fluid bolus 20ml/kg
    e. Oxygenation with 100% 02
    f. Afterload reduction
    g. A, B, C, D
    h. B, D, E, F
    i. D, E, C, F
    j. A, B, C, E
    k. A, B, D, E
    l. All of the above
    m. None of the above

Appendix B

Key

1) **B (**Welborn, De Soto, Hannallah, Fink, Ruttimann, & Boeckx, 1988)

2) **C (**Yuki, Casta, & Uezono, 2011)

3) **A** (Isolated Pierre Robin sequence, 2016)

4) **D** (Graziano, 2005)

5) **B** (Tsiligiannis & Grivas, 2012)

6) **A** (Aspelund & Langer, 2007)

7) **C** (Faraoni & Goobie, 2014)

8) **C** (Aspelund & Langer, 2007)

9) **E** (Landsman, Wekhaven, & Motoyama, 2011)

10) **K** (Gewillig, 2005)

Appendix C

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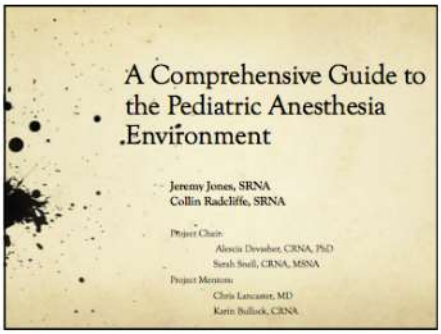

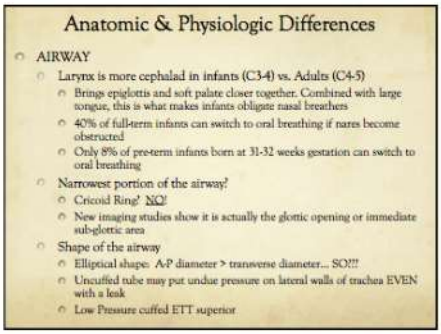

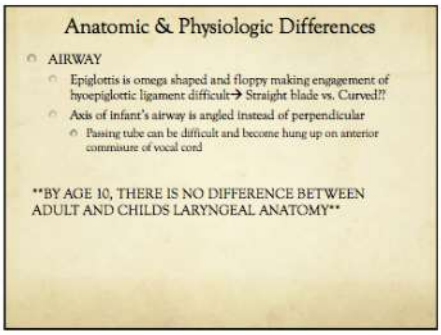

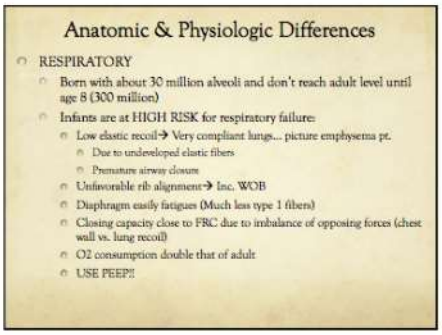

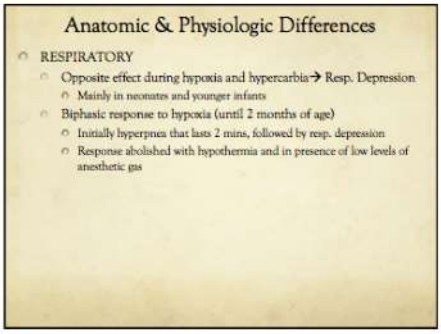

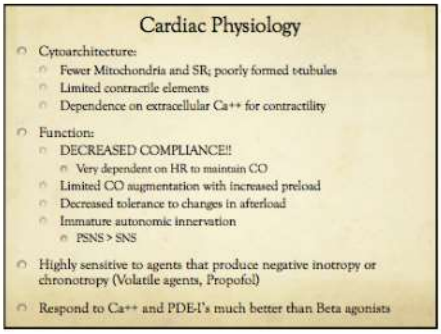

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3/13/17

Urologic Procedures

HYPOSPADIAS/CHORDEE REPAIR; CIRCUMCISION

- Concomitant disorders: Usually isolated anatomical malformation-- Circumcision usually elective, however phimosis may be the culprit in older children
- Position: Supine
- Surgical Time:
  - Circumcision- 30 mins.
  - Hypospadias- 1-4 hrs.
- Anesthesia Management: General Anesthesia
  - Circumcision may be a mask management case, LMA, or ETT depending on comorbidities. Usually LMA
  - Hypospadias/Chordee: Done with ETT if < 1 yr of age. Otherwise, LMA is usually the choice
  - Make sure patient does not move... the work is very meticulous

Urologic Procedures

HYPOSPADIAS/CHORDEE REPAIR; CIRCUMCISION

- Post-Op: Usually outpatient procedures
  - If the hypospadias requires advanced techniques or two stage procedure the child may be admitted
  - Caudal catheter may be indicated for pain control in the above situation
- Special Considerations:
  - Penile block is often performed by the surgeon
  - Make sure if using an LMA that the child has an appropriate level of anesthetic because the block is very stimulating and can cause laryngospasm!
  - If admitted with caudal catheter, discuss with surgeon about plans for a urethral catheter as the caudal may cause urinary retention

Urologic Procedures

ORCHIDECTOMY/ORCHIOPEXY

- Concomitant disorders: cryptorchidism, testicular torsion
- Position: Supine
- Surgical Time: ~ 1 hour
- Anesthesia Management: General Anesthesia
  - Usually an LMA is utilized if the patient is > 1 yr
  - Testicular Torsion: assume full stomach→ RSI
  - Ensure at least 1.5-2 MAC at incision to prevent laryngospasm
- Post-Op: Outpatient Procedure
- Special Considerations:
  - Ilioinguinal nerve block and caudal analgesia are equally effective for post-orchiopexy pain, but realize that urinary retention is a possible risk
  - Testicular Torsion is a true urologic emergency!! Surgery should commence within 6 hours of onset of symptoms in order to save the testis

Urologic Procedures

LAPRASCOPIC HEMINEPHRECTOMY, NEPHROURETERECTOMY, & PYELOPLASTY

- Concomitant Disorders: UPJ obstruction, non-functioning kidney, Renal cysts, HTN in ESRD, Renal Tumors
- Position: Lateral Decubitis with trendelenburg or jackknife
- Surgical Time: 2.5-4 hours
- Anesthesia Management: GETA
  - Watch pressures when masking on induction so as not to overinflate the stomach
  - May need to place OGT to decompress stomach prior to insufflation of abdomen to avoid inadvertent trocar placement into stomach
  - Pressure control ventilation is often needed once trendelenburg is instituted
- Post-Op: Admitted after PACU
- Special Considerations:
  - Often there is underlying Renal Insufficiency so take that into consideration when choosing drugs that are eliminated via the kidneys
  - Patients often anemic d/t erythropoietin deficiency

General Surgery

INGUINAL & UMBILICAL HERNIA REPAIR

- Concomitant Disorders: prematurity, respiratory illness are risk factors for inguinal hernias. However, most patients are otherwise healthy
- Position: Supine
- Surgical Time: 30-45 mins.
- Anesthesia Management: General Anesthesia
  - Umbilical hernias are usually not done until the child is ~2 yrs old so LMA is fine if done open
  - Inguinal Hernia- GETA if < 1 yr old, otherwise LMA is usually ok
  - If LMA, patient may laryngospasm upon manipulation of the hernia sac so make sure 1.5-2 MAC prior to this
  - Former premature infants at risk for postop apnea
    - Spinal anesthesia with sedation may be preferred in order to avoid general anesthesia
    - Rare and requires high degree of skill as infant will not be cooperative for placement
- Post-Op: Outpatient surgery
- Special Considerations:
  - Apnea monitor and pulse oximeter for 12 – 18 h for all patients < 44 wks, born before 37 wks with current age <52 wks, and premature infants <60 wks

General Surgery

PYLOROMYOTOMY

- Concomitant Disorders: Pyloric stenosis→ commonly hypochloremic, hypokalemic met. Alkalosis d/t protracted vomiting; dehydration→ polycythemia
- Position: Supine
- Surgical Time: 30-60 mins.
- Anesthesia Management: GETA
  - RSI
  - Suctioning of an in-situ NGT is not sufficient to empty the stomach--A wide bore OGT should be placed and the stomach should be suctioned thoroughly PRIOR to induction of anesthesia
    - Have atropine available or pre-treat b/c this can often induce bradycardia
  - Avoid opioids--they can worsen hypoventilation in an infant that is already prone to hypoventilate d/t pre-existing alkalosis
  - Rectal acetaminophen is helpful for post op analgesia
  - Maintain muscle relaxation and reverse with neostigmine and atropine (neonates are not as responsive to glycopyrrolate)
  - Suction stomach prior to extubation

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General Surgery

PYLOROMYOTOMY

- Special Considerations:
  - Pyloromyotomy is NOT a surgical Emergency!
  - It is important to correct fluid & acid/base derangements prior to induction of anesthesia
  - If performed laparoscopically, insufflation can cause severe hypotension in the hypovolemic neonate

General Surgery

TRACHEOESOPHAGEAL FISTULA REPAIR

- Concomitant Disorders: Common VACTERL association→ Vertebral anomalies, imperforate anus, congenital heart defects, TEF, renal abnormalities & limb abnormalities
  - ~85% have esophageal atresia with a distal TEF (type C)
  - Prematurity→ RDS?
- Position: Lateral decubitus with a thoracotomy incision on the side OPPOSITE the aortic arch
  - Often done thoracoscopically in neonates with decent lung and cardiac function
- Surgical Time: 2-4 hrs.

General Surgery

TRACHEOESOPHAGEAL FISTULA REPAIR

- Anesthesia Management: GETA
  - IV induction–avoid mask ventilation if possible
  - Intubate the right mainstem and then pull the ETT just until bilateral breath sounds are present. Then, rotate the ETT so the bevel faces posteriorly in order to avoid intubating the fistula. Verify with fiberoptic bronchoscope
  - Keep PIP <25 cmH2O is possible in order to avoid gastric distention
  - Muscle relaxation is usually needed throughout surgery
  - Avoid high FiO2 as these patients are often premature and are at risk for retinopathy
  - Surgeon may instruct you to pass a small gastric tube into the blind pouch to identify the structure for anastomosis once the TEF is ligated
- Post-Op:
  - Extubation preferred, but may not be possible depending on comorbidities
  - May be left intubated and taken to ICU for 24-48 hrs

ENT

MYRINGOTOMY & TYMPANOSTOMY TUBES

- Concomitant Disorders:
  - Chronic otitis media
  - Common in patients with cleft palate
  - Down syndrome→ due to stenotic ear canals, which can prolong surgery
- Position: supine with head to anesthesia
- Surgical Time: 5-10 mins
  - Learn to mask and chart simultaneously

ENT

Myringotomy & Tympanostomy Tubes

- Anesthesia Management: General Anesthesia
  - Inhalation induction
  - Usually done with no IV placement
  - Mask management for length of case
  - Procedure is very stimulating so keep the patient DEEP to avoid laryngospasm
  - Can give intranasal fentanyl after asleep for pain control
  - Gentle oropharyngeal suctioning at end of procedure
- Post-Op: Outpatient
  - Premedication with versed may delay PACU discharge especially when combined with intra-op fentanyl
- Special Considerations:
  - Intra-op fentanyl helps decrease emergence delirium

ENT

TONSILLECTOMY & ADENOIDECTOMY

- Concomitant Disorders:
  - Tonsillitis/adenoiditis
  - OSA
  - Tonsillar and adenoid hypertrophy
- Position:
  - Supine with shoulder roll and head extended
  - Table turned 90 degrees
- Surgical Time: 30-45 mins.
- Anesthesia Management: General Anesthesia
  - GETA→ ETT taped down at center of chin
  - Can use Oral RAE, but not necessary
  - High incidence of N/V, which can cause re-bleeding
  - Surgeon will often suction the oropharynx at the end of surgery–If not, do it yourself, but ONLY suction midline
  - Preferable to extubate fully awake, but some extubate deep in order to avoid coughing
  - For smooth emergence, consider dexmedetomidine

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ENT

TONSILLECTOMY & ADENOIDECTOMY

- Post-Op: Outpatient
  - Premedication with steroid may delay PACU discharge especially when combined with intra-op fentanyl
  - Lateral position on transport to PACU
- Special Considerations:
  - Greater incidence of respiratory complications on induction when indication is OSA vs. chronic tonsillitis
  - If patient has down syndrome, assess for atlantoaxial subluxation→ Head extension may not be feasible
  - Watch for kinking of ETT by the mouth gag→ pay attention while surgeon is placing it
  - Severity of OSA and post-op complications have a linearly proportional relationship
  - High incidence of laryngospasm
  - Pts with OSA & nocturnal desat. To < 85% have an upregulation of the genes responsible for control of opioid receptors, resulting in an increased sensitivity to opioids → CUT DOSES IN HALF

Orthopedic Procedures

POSTERIOR SPINAL INSTRUMENTATION

- Concomitant Disorders
  - Scoliosis/kyphosis
    - 140% of cases are due to either idiopathic (80-170th scoliosis or neuromuscular scoliosis (20-35%)
    - Restrictive lung disease
    - Pulm HTN
  - Trauma
- Congenital Scoliosis
  - ~10% incidence of cardiac abnormalities
  - Bracing/casting NOT effective
- Idiopathic Scoliosis
  - Infantile= birth-3 years (<1%)
    - Casting useful in select cases
      - OITN
      - Watch for CO desat. When cast is applied
      - Place OBS in patients immediately post-op
  - Juvenile= 4-10 yrs (10-15%)
    - Bracing/casting not very successful

Orthopedic Procedures

POSTERIOR SPINAL INSTRUMENTATION

- Anesthesia Management: GETA
  - After induction of anesthesia an arterial line is always placed. A central venous line may be placed if large blood loss is anticipated
  - TIVA is preferred due to SSEP and MEP monitoring
    - Propofol gtt & remifentanil gtt most commonly
  - At most a 0.5 MAC of volatile agent should be used with narcotic gtt to augment anesthesia
  - Ancure 100 mg/kg bolus given up front, followed by 10mg/kg/hr infusion
  - 0.5 mcg/kg clonidine AND 1 mcg/kg dexmedetomidine given by surgeon directly into surgical site
  - Ketamine intermittent bolus or infusion common
  - Maintain MAP at 60-70 mmHg to control blood loss
  - Most patients are extubated at the end of surgery.
    - Pts with severe respiratory impairment preop may need postop ventilation
  - Postop pain may be controlled with other IV opioids, Thoracic epidural analgesia, paravertebral block, or a combination of any

Orthopedic Procedures

POSTERIOR SPINAL INSTRUMENTATION

- Post-Op: Inpatient
- Special Considerations
  - Blood loss is substantial→ Have adequate IV access for blood/fluid replacement
  - ~20% of children with juvenile scoliosis and infantile scoliosis (with curve > 20%) have Arnold-Chiari malformation and/or syringomyelia
    - Review CNS imaging for extent of malformation and asses for neuro deficits and cervical spine immobility
  - Neuromusc. Scoliosis carries greater risk of aspiration and resp. failure

CONGENITAL CARDIAC PROCEDURES

- NORWOOD (Stage 1 for Single Ventricle Physiology)
- Concomitant Disorders
  - Hypoplastic Left Heart Syndrome
  - Pulmonary Atresia with Intact Ventricular Septum
  - Tricuspid Atresia
- Position: Supine
- Surgical Time: Wide Variation- 4-12 hours
- Anesthesia Management: General Anesthesia with Cardiopulmonary Bypass, High Dose Opioid preferred
- Post-Op: Inpatient, Straight to ICU

CONGENITAL CARDIAC PROCEDURES

- NORWOOD (Stage 1 for Single Ventricle Physiology)
- Before this surgery can be done, there are requirements, there must be a patent ASD and PDA. If the ASD is restrictive, a balloon atrial septostomy can be emergently done after birth to provide a path for blood to mix. The PDA will often require prostin to maintain the patency.
- Primary goal is optimizing Q_P/Q_S through SVR and PVR, avoid hyperventilation and/or hypoventilation, hypoxemia and hyperthermia.
- This surgery is usually performed in the 1st 2 weeks of life.
- Before this surgery and until the Glenn is performed, the infant's state is extremely precarious.

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CONGENITAL CARDIAC PROCEDURES

- NORWOOD (CONTINUED)

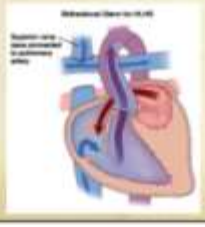
Brief Surgical Description: A new aorta is created using the pulmonary artery in conjunction and unalignation with whatever viable aortic tissue can be utilized. There is now no pulmonary blood flow d/t utilization of the PA for the neoaorta. This is alleviated with an aortopulmonary shunt: a BT (Blalock-Taussig) shunt is placed from an artery (usually the brachiocephalic) directly to the RPA, another option is a Sano shunt which is larger and goes directly from the ventricle to the pulmonary artery.

CONGENITAL CARDIAC PROCEDURES

- BI-DIRECTIONAL GLENN (Stage 2 for Single Ventricle Physiology)

CONGENITAL CARDIAC PROCEDURES

- Bi-Directional Glenn



Brief Surgical Description: The second stage of surgical procedure for single ventricle physiology is referred to as the Glenn (Bi-Directional Glenn) procedure. During the procedure the previous shunt providing pulmonary blood flow will be taken down and pulmonary blood flow will now be provided passively be connecting the SVC directly to the pulmonary artery. At this point, the ventricle pumps blood to the body and the bottom half drains back to the heart while the top half of the body will drain directly to the lungs picking up oxygenated blood. Saturations will generally be in the 75%-85% range at this point.

CONGENITAL CARDIAC PROCEDURES

- FONTAN PROCEDURE (Stage 3 for Single Ventricle Physiology)

CONGENITAL CARDIAC PROCEDURES

- FONTAN PROCEDURE (Stage 3 for Single VentriCle Physiology)

Brief Surgical Description: The IVC is connected to the pulmonary circulation, completing the closed circuit. This can be accomplished via an extracardiac or intracardiac conduit which essentially extends and connects the IVC to provide a secure cavopulmonary anastomosis. At this point the single ventricle pumps only to the body, ALL venous drainage is now to the lungs providing two separate circuits and restoring the body back to its original 2 circuit physiology.

CONGENITAL CARDIAC PROCEDURES

- TETRALOGY OF FALLOT (MOST COMMON CYANOTIC DEFECT)

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CONGENITAL CARDIAC PROCEDURES

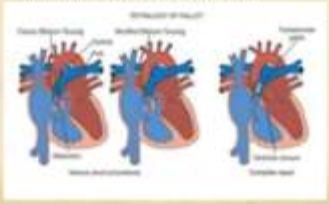
- TETRALOGY OF FALLOT
- Special Considerations
  - This disease can be initially palliated or a complete repair can be done. If a simple shunt is placed to bypass the RVOTO, CPB is usually not required and the case is relatively short. If complete repair of all defects occurs, CPB is required and the case is significantly longer.
  - Central and arterial access (If only access, place A-line opposite side of shunt)
  - Mitigate crying/stress to avoid hypercyanotic episodes
  - Inhalational vs IV induction
  - Ketamine helps provide inotropic and heartrate
  - Fentanyl, Isoflurane may worsen RVOTO
  - ICP is common start up if considering all risks, avoid paralytics and succinate here, only as those trigger ICP
  - BV dysfunction and Pulmonary regurgitation can occur postop
  - BG pressure measurement help assess quality of the repair

CONGENITAL CARDIAC PROCEDURES

- TET SPELL AKA HYPERCYANOTIC SPELL
- Rapid desaturation and intense cyanosis
  - Remember that these children have an obstruction from the RV to the PA as well as a VSD, this means that anything that narrows the systemic vascular resistance (SVR) can cause excessive blood to be diverted across the VSD from Right to Left, severely limiting pulmonary blood flow.
- Interventions for TET Spell
  - Phenylephrine: 0.5-1 mcg/kg
  - Neosynephrine: 0.5 mcg/kg bolus followed by 0.01-0.2 mcg/kg/min
  - 100% O2 with Hyperventilation
  - IV fluid bolus: 10-20 ml/kg
  - Fentanyl: 1-3 mcg/kg or Morphine: 0.1-0.3 mg/kg
  - Propranolol: 0.1-0.5 mg/kg bolus (Reduces infundibular spasm)
  - Bring legs to chest and/or knee-chest (calf squat)

CONGENITAL CARDIAC PROCEDURES

- TETRALOGY OF FALLOT REPAIR



CONGENITAL CARDIAC DISEASE

- Classification of CHD:
- Simple Left to Right: Increased Pulmonary Blood Flow (Acyanotic Defect)
  - Atrial Septal Defect (ASD)
  - Ventricular Septal Defect (VSD)
  - Patent Ductus Arteriosus (PDA)
  - Endocardial cushion defect (Atrioventricular septal defect (AVSD))
  - Aortopulmonary window (AP window)
- Simple Right to Left: Decreased Pulmonary Blood Flow (Cyanotic Defect)
  - Tetralogy of Fallot (TOF)
  - Pulmonary Atresia
  - Tricuspid Atresia
  - Ebstein Anomaly

CONGENITAL CARDIAC DISEASE

- Classification of CHD:
- Complex Shunts: Mixing of Deoxygenated and Systemic Blood Flow with Cyanosis
  - Transposition of the great arteries (TGA)
  - Truncus Arteriosus
  - Total anomalous pulmonary venous connection (TAPVC)
  - Double outlet right ventricle (DORV)
  - Hypoplastic left heart syndrome (HLHS)
- Obstructive Lesions
  - Aortic Stenosis
  - Mitral Stenosis
  - Pulmonary Stenosis
  - Coarctation of aorta
  - Interrupted aortic arch

CONGENITAL CARDIAC DISEASE

- General Goals
- Physical Examination
  - Failure to thrive
  - Difficult feeding
  - Breathlessness
  - Recurrent chest infection
  - Tachycardia
  - Cardiac murmur
  - Hepatomegaly
  - Cardiomegaly
  - Pulmonary plethora
  - Wheezing
- Common Considerations
  - Avoid air bubbles in setting of a possible arterial embolus
  - Avoid 100% O2, have AED available for emergency
  - One of the only pediatric situations where bradycardia may not be always deleterious, do not hyperventilate if you do not know the disease process

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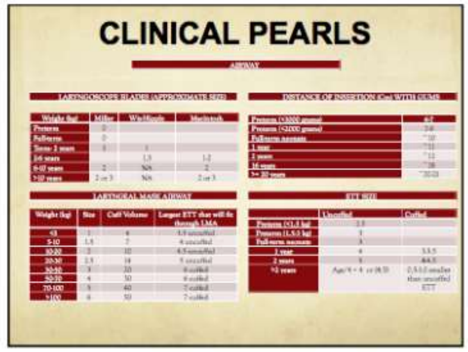
CONGENITAL CARDIAC DISEASE

- Common Congenital Associations with Cardiac Anomalies:
  - **VACTERL**: Vertebral anomalies, Anal atresia, Cardiac defect, TracheoEsophageal atresia, Renal anomalies, & Limb abnormalities.
  - **CHARGE**: Coloboma of the eye, Heart defects, Atresia of the choanae, Retardation of growth and development, Genitourinary defects, & Ear anomalies.
  - **CATCH-22** (mnemonic for DiGeorge syndrome): Cardiac defect, Abnormal facies, Thymic hypoplasia, Cleft palate, Hypocalcemia & 22q11 chromosome microdeletion.



REFERENCES

Aspelund, G., & Langer, J. C. (2007). Current management of hypertrophic pyloric stenosis. *Seminars in Pediatric Surgery, 16*(1), 27-33. http://dx.doi.org/10.1053/j.sempedsurg.2006.10.004

Beecher, H. P., & Todd, D. P. (1954). A study of the deaths associated with anesthesia and surgery. *Annals of Surgery*, 140, 2-34.

Bharanker, S. M., Ramamoorthy, C., Geiduschek, J. M., Posner, K. L., Domino, K. B., Haberkern, C. M., ... Morray, J. P. (2007). Anesthesia-related cardiac arrest in children: Update from the pediatric perioperative cardiac arrest registry. *Anesthesia & Analgesia*, 105(2), 344-350. http://dx.doi: 10.1213/01.ane.0000268712.00756.dd

Coté, C. J., Lerman, J., & Anderson, B. J. (2013). Coté and Lerman's a practice of anesthesia for infants and children. Philadelphia, PA: Elsevier/Saunders.

Davis, P. J., Cladis, F. P., & Motoyama, E. K. (2010). Smith's Anesthesia for Infants and Children: Expert Consult Premium. London: Elsevier Health Sciences.

Faraoni, D., & Goobie, S. M. (2014). The efficacy of antifibrinolytic drugs in children undergoing noncardiac surgery: a systematic review of the literature. Anesthesia and Analgesia, 118(3), 628-36. http://dx.doi.org/10.1213/ANE.0000000000000080

REFERENCES

Gewillig, M. (2005). The Fontan Circulation. Heart, 91(6), 839-846. http://dx.doi.org/10.1136/hrt.2004.051789

Graziano, J. N. (2005). Cardiac anomalies in patients with congenital diaphragmatic hernia and their prognosis: a report from the Congenital Diaphragmatic Hernia Study Group. Journal of Pediatric Surgery, 40(6), 1045-9. Retrieved from http://dx.doi.org/10.1016/j.jpedsurg.2005.03.025

Hagerman, N. S., Varughese, A. M., & Kurt, C. D. (2014). Quality and safety in pediatric anesthesia: how can guidelines, checklists, and initiatives improve the outcome? *Current Opinions in Anesthesiology*, 27(3), 323-329. http://dx.doi.org/10.1097/ ACO.0000000000000078

Isolated Pierre Robin sequence. (2016, July 16). Retrieved from https://ghr.nlm.nih.gov/condition/isolated-pierre-robin-sequence

JLR Medical Group. (n.d.). www.jlrmedicalgroup.com

Landsman, I. S., Wekhaven, J. A., & Motoyama, E. K. (2011). Anesthesia for pediatric otorhinolaryngologic surgery. In Smith's Anesthesia for Infants and Children (8th ed.). Philadelphia: Elsevier.

REFERENCES

Subramanyam, R., Yeramaneni, S., Hossain, M. M., Anneken, A. M., & Varughese, A. M. (2016). Perioperative respiratory adverse events in pediatric ambulatory anesthesia. *Anesthesia & Analgesia*, 122(5), 1578-1585. http://dx.doi.org/ 10.1213/ane.0000000000001216

The American Academy of Pediatrics. (2015). Critical elements for the pediatric perioperative anesthesia environment. PEDIATRICS, 136(6), 1200-1206. http://dx.doi.org/10.1542/peds.2015-3595

Tobias, J. D. (2014). Pediatric airway anatomy may not be what we thought: implications for clinical practice and the use of cuffed endotracheal tubes. *Pediatric Anesthesia*, 25(1), 9-19. http://dx.doi.10.1111/pan.12528 (reference for points 1&2)

Tsiligiannis, T., & Grivas, T. (2012). Pulmonary function in children with idiopathic scoliosis. Scoliosis, 23(7). doi: 10.1186/1748-7161-7-7

Wacker, J., & Kolbe, M. (2016). The challenge of learning from perioperative patient harm. Trends in Anaesthesia and Critical Care, 7(8), 5-10. Retrieved from http://dx.doi.org/10.1016/j.tacc.2016.03.003

Welborn, L. G., De Soto, H., Hannallah, R. S., Fink, R., Ruttimann, U. E., & Boeckx, R. (1988). The use of caffeine in the control of post-anesthetic apnea in former premature infants. *Anesthesiology*, 68(5), 796-798.

Yuki, K., Casta, A., & Uezono, S. (2011). Anesthetic management of noncardiac surgery for patients with single ventricle physiology. *Journal of Anesthesiology*, 25(2), 247-256.

REFERENCES

Landsman, I. S., Wekhaven, J. A., & Motoyama, E. K. (2011). Anesthesia for pediatric otorhinolaryngologic surgery. In Smith's Anesthesia for Infants and Children (8th ed.). Philadelphia: Elsevier.

Rackow, H., Salinitre, E., & Green, L. (1961). Frequency of cardiac arrest associated with anesthesia in infants and children. *Pediatrics*, 28, 697-704.

Salem, M., Bennett, E., Schweiss, J., Baraka, A., Dallas, F., & Collins, V. (1975). Cardiac arrest related to anesthesia: Contributing factors in infants and children. *Journal of the American Medical Association*, 233, 238-41.

Schleelein, L. E., Vincent, A. M., Jawad, A. F., Pruitt, E. Y., Kreher, G. D., Rehman, M. A., ... Cook-Sather, S. D. (2016). Pediatric perioperative adverse events requiring rapid response: a retrospective case-control study. *Pediatric Anesthesia*, 26(7), 734-741. http://dx.doi.org/10.1111/pan.12922

Subramanyam, R., Yeramaneni, S., Hossain, M. M., Anneken, A. M., & Varughese, A. M. (2016). Perioperative respiratory adverse events in pediatric ambulatory anesthesia. *Anesthesia & Analgesia*, 122(5), 1578-1585. http://dx.doi.org/ 10.1213/ane.0000000000001216

The American Academy of Pediatrics. (2015). Critical elements for the pediatric perioperative anesthesia environment. *PEDIATRICS*, 136(6), 1200-1206. http://dx.doi.org/10.1542/peds.2015-3595

Appendix D

UROLOGIC PROCEDURES

HYPOSPADIA/CHORDEE REPAIR; CIRCUMCISION

- Concomitant disorders: Usually isolated anatomical malformation— Circumcision usually elective, however phimosis may be the culprit in older children

- Position: Supine

- Surgical Time:
  - Circumcision- 30 mins.
  - Hypospadias- 1-4 hrs.

- Anesthesia Management: General Anesthesia
  - Circumcision may be a mask management case, LMA, or ETT depending on comorbidities. Usually LMA
  - Hypospadias/Chordee- Done with ETT if < 1 yr of age. Otherwise, LMA is usually the choice
  - Make sure patient does not move… the work is very meticulous

- Post-Op: Usually outpatient procedures
  - If the hypospadias requires advanced techniques or two stage procedure the child may be admitted
  - Caudal catheter may be indicated for pain control in the above situation

- Special Considerations:
  - Penile block is often performed by the surgeon
  - Make sure if using an LMA that the child has an appropriate level of anesthetic because the block is very stimulating and can cause laryngospasm!
  - If admitted with caudal catheter, discuss with surgeon about plans for a urethral catheter as the caudal may cause urinary retention

UROLOGIC PROCEDURES

ORCHIECTOMY/ORCHIOPEXY

- Concomitant disorders: cryptorchidism, testicular torsion
- Position: Supine
- Surgical Time: ~ 1 hour
- Anesthesia Management: General Anesthesia
    - Usually an LMA is utilized if the patient is > 1 yr
    - Testicular Torsion: assume full stomach→ RSI
    - Ensure at least 1.5-2 MAC at incision to prevent laryngospasm
- Post-Op: Outpatient Procedure
- Special Considerations:
    - Ilio-inguinal nerve block and caudal analgesia are equally effective for post-orchiopexy pain, but realize that urinary retention is a possible risk
    - Testicular Torsion is a true urologic emergency!! Surgery should commence within 6 hours of onset of symptoms in order to save the testis

UROLOGIC PROCEDURES

LAPAROSCOPIC HEMINEPHRECTOMY, NEPHROURETERECTOMY, PYELOPLASTY

- Concomitant Disorders: UPJ obstruction, non-functioning kidney, Renal cysts, HTN in ESRD, Renal Tumors

- Position: Lateral Decubitis with trendelenburg or jackknife

- Surgical Time: 2.5-4 hours

- Anesthesia Management: GETA
    - Watch pressures when masking on induction so as not to over-inflate the stomach
    - May need to place OGT to decompress stomach prior to insufflation of abdomen to avoid inadvertent trocar placement into stomach
    - Pressure control ventilation is often needed once trendelenburg is instituted

- Post-Op: Admitted after PACU

- Special Considerations:
    - Often there is underlying Renal Insufficiency so take that into consideration when choosing drugs that are eliminated via the kidneys
    - Patients often anemic d/t erythropoietin deficiency

GENERAL SURGERY

INGUINAL & UMBILICAL HERNIA REPAIR

- Concomitant Disorders: prematurity, respiratory illness are risk factors for inguinal hernias. However, most patients are otherwise healthy

- Position; Supine

- Surgical Time: 30-45 mins.

- Anesthesia Management: General Anesthesia
    - Umbilical hernias are usually not done until the child is ~2 yrs olf so LMA is fine if done open
    - Inguinal Hernia- GETA if < 1 yr old, otherwise LMA is usually ok
    - If LMA, patient may laryngospasm upon manipulation of the hernia sac so make sure 1.5-2 MAC prior to this
    - Former premature infants at risk for post-op apnea:
        - Spinal anesthesia with sedation may be preferred in order to avoid general anesthesia
        - Rare and requires high degree of skill as infant will not be cooperative for placement
- Post-Op: Outpatient surgery

- Special Considerations:
    - Apnea monitor and pulse oximeter for 12– 18 h for: all patients < 44 wks, born before 37 wks with current age <52 wks; and premature infants <60 wks

GENERAL SURGERY

PYLOROMYOTOMY

- Concomitant Disorders: Pyloric stenosis→ commonly hypochloremic, hypokalemic met. Alkalosis d/t protracted vomiting; dehydration→ polycythemia
- Position: Supine
- Surgical Time: 30-60 mins.
- Anesthesia Management: GETA
    - RSI
    - Suctioning of an in-situ NGT is not sufficient to empty the stomach—A wide bore OGT should be placed and the stomach should be suctioned thoroughly PRIOR to induction of anesthesia
        - Have atropine available or pre-treat b/c this can often induce bradycardia
    - Avoid opioids—they can worsen hypoventilation in an infant that is already prone to hypoventilate d/t pre-existing alkalosis
    - Rectal acetaminophen is helpful for post op analgesia
    - Maintain muscle relaxation and reverse with neostigmine and atropine (neonates are not as responsive to glycopyrrolate)
    - Suction stomach prior to extubation
- Special Considerations:
    - Pyloromyotomy is NOT a surgical Emergency!
    - It is important to correct fluid & acid/base derangements prior to induction of anesthesia
    - If performed laparoscopically, insufflation can cause severe hypotension in the hypovolemic neonate

GENERAL SURGERY

TRACHEOESOPHAGEAL FISTULA REPAIR

- Concomitant Disorders: Common VACTERL association→ Vertebral anomalies, imperforate anus, congenital heart defects, TEF, renal abnormalities & limb abnormalities
    - ~85% have esophageal atresia with a distal TEF (type C)
    - Prematurity→ RDS?
    -
- Position: Lateral decubitus with a thoracotomy incision on the side OPPOSITE the aortic arch
    - Often done thoracoscopically in neonates with decent lung and cardiac function

- Surgical Time: 2-4 hrs.

- Anesthesia Management: General Anesthesia
    - IV induction—avoid mask ventilation if possible
    - Intubate the right mainstem and then pull the ETT just until bilateral breath sounds are present. Then, rotate the ETT so the bevel faces posteriorly in order to avoid intubating the fistula. Verify with fiberoptic bronchoscope
    - Keep PIP <25 cmH2O is possible in order to avoid gastric distention
    - Muscle relaxation is usually needed throughout surgery
    - Avoid high FiO2 as these patients are often premature and are at risk for retinopathy
    - Surgeon may instruct you to pass a small gastric tube into the blind pouch to identify the structure for anastomosis once the TEF is ligated
- Post-Op: Inpatient
    - Patients are usually left intubated and taken to ICU for 24-48 hrs

- Special Considerations:
    - If the neonate looks at all like a difficult intubation, an "awake" intubation should be carried out

ENT

MYRINGOTOMY & TYPANOSTOMY TUBES

- Concomitant Disorders:
    - Chronic otitis media
    - Common in patients with cleft palate
    - Down syndrome→ due to stenotic ear canals, which can prolong surgery
- Position: Supine with head to anesthesia
- Surgical Time: 5-10 mins
    - Learn to mask and chart simultaneously
- Anesthesia Management: General Anesthesia
    - Inhalation induction
    - Usually done with no IV placement
    - Mask management for length of case
    - Procedure is very stimulating so keep the patient DEEP to avoid laryngospasm
    - Can give intranasal fentanyl after asleep for pain control
    - Gentle oropharyngeal suctioning at end of procedure
- Post-Op: Outpatient
    - Premedication with versed may delay PACU discharge especially when combined with intra-op fentanyl
- Special Considerations:
    - Intra-op fentanyl helps decrease emergence delirium

ENT

TONSILLECTOMY & ADENOIDECTOMY

- Concomitant Disorders:
  - Tonsillitis/adenoiditis
  - OSA
  - Tonsillar and adenoid hypertrophy
- Position:
  - Supine with shoulder roll and head extended
  - Table turned 90 degrees
- Surgical Time: 30-45 mins.
- Anesthesia Management: General Anesthesia
  - GETA→ ETT taped down at center of chin
  - Can use Oral RAE, but not necessary
  - High incidence of N/V, which can cause re-bleeding
  - Surgeon will often suction the oropharynx at the end of surgery—If not, do it yourself, but ONLY suction midline
  - Preferable to extubate fully awake, but some extubate deep in order to avoid coughing
  - For smooth emergence, consider dexmedetomidine
- Post-Op: Outpatient
  - Premedication with versed may delay PACU discharge especially when combined with intra-op fentanyl
  - Lateral position on transport to PACU
- Special Considerations:
  - Greater incidence of respiratory complications on induction when indication is OSA vs. chronic tonsillitis
  - If patient has down syndrome, assess for atlantoaxial subluxation→ Head extension may not be feasible
  - Watch for kinking of ETT by the mouth gag→ pay attention while surgeon is placing it
  - Severity of OSA and post-op complications have a linearly proportional relationship
  - High incidence of laryngospasm
  - Pts with OSA & nocturnal desat. To < 85% have an upregulation of the genes responsible for control of opioid receptors, resulting in an increased sensitivity to opioids → CUT DOSES IN HALF
  - Bleeding can occur (0.5-2%), 75% within 1st 6 hrs.

ORTHOPEDIC PROCEDURES

POSTERIOR SPINAL INSTRUMENTATION

- Concomitant Disorders:
  - Scoliosis/kyphosis
    - >80% of cases are due to either idiopathic (50-75%) scoliosis or neuromuscular scoliosis (20-35%)
    - Restrictive lung disease
    - Pulm HTN
  - Trauma
- Congenital Scoliosis
  - ~10% incidence of cardiac abnormalities
  - Bracing/casting NOT effective
- Idiopathic Scoliosis
  - Infantile= birth-3 years (<1%)
    - Casting useful in select cases
      - GETA!
      - Watch for O2 desat. When cast is molded!
      - Place OPA to prevent compression of ETT from chin strap
  - Juvenile= 4-10 yrs (10-15%)
    - Bracing/casting not very successful
- Position: Prone
- Surgical Time: 2-6 hours
- Anesthesia Management: GETA
  - After induction of anesthesia an arterial line is always placed. A central venous line may be placed if large blood loss is anticipated
  - TIVA is preferred due to SSEP and MEP monitoring
    - Propofol gtt & remifentanil gtt most commonly
  - At most a 0.5 MAC of volatile agent should be used with narcotic gtt to augment anesthesia
  - Amicar 100 mg/kg bolus given up front, followed by 10mg/kg/hr infusion
  - 0.5 mcg/kg clonidine AND 3 mcg/kg duramorph given by surgeon directly into surgical site
  - Ketamine intermittent bolus or infusion common
  - Maintain MAP at 60-70 mmHg to control blood loss
  - Most patients are extubated at the end of surgery.
    - Pts with severe respiratory impairment pre-op may need post-op ventilation
  - Post-op pain may be controlled with either IV opioids, Thoracic epidural analgesia, paravertebral block, or a combination of any

- Post-Op: Inpatient

- Special Considerations
  - Blood loss is substantial→ Have adequate IV access for blood/fluid replacement
  - ~20% of children with juvenile scoliosis and infantile scoliosis (with curve > 20%) have Arnold-Chiari malformation and/or syringomyelia
    - Review CNS imaging for extend of malformation and asses for neuro defiicts and cervical spine immobility
  - Neuromusc. Scoliosis carries greater risk of aspiration and resp. failure

CONGENITAL CARDIAC PROCEDURES

NORWOOD (Stage 1 for Single Ventricle Physiology)

- Concomitant Disorders:
  - Hypoplastic Left Heart Syndrome
  - Pulmonary Atresia with Intact Ventricular Septum
  - Tricuspid Atresia

- Position: Supine

- Surgical Time: Wide Variation- 4-12 hours

- Anesthesia Management: General Anesthesia with Cardiopulmonary Bypass, High Dose Opioid preferred

- Post-Op: Inpatient, Straight to ICU

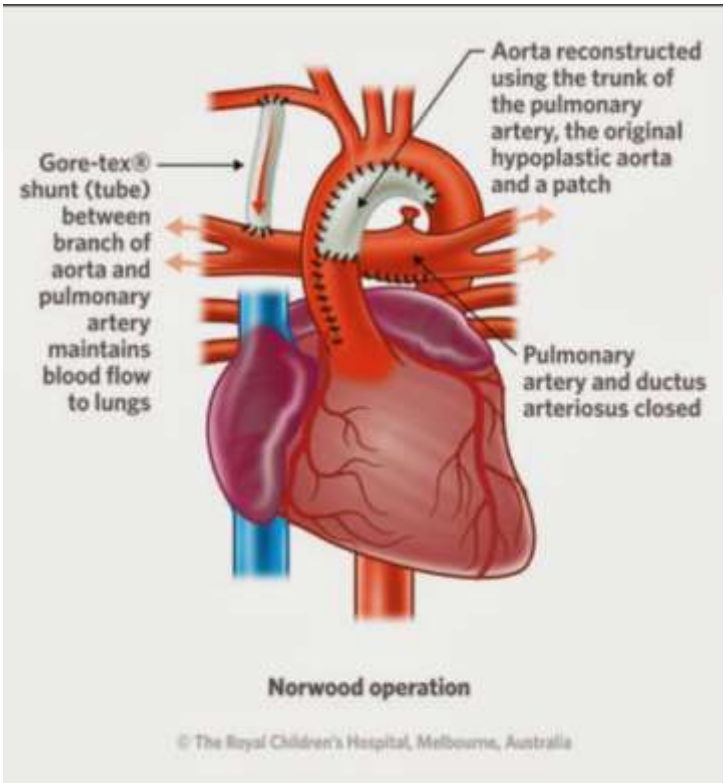
- Special Considerations:

  - The primary goal in the management of patients with single ventricle physiology is optimizing systemic oxygen delivery and perfusion pressure. This is achieved by balancing systemic and pulmonary circulations (Qp:Qs). It´s important to **avoid hyperventilation and hyperoxia** (**Use AIR**) because it would reduce Pulmonary Vascular Resistance (PVR) and cause pulmonary "overcirculation"; Hypoxia and Hypercarbia will elevate PVR and cause pulmonary "undercirculation". SaO2 must be kept between 75-80% and SaO2-SmvO2 between 25-30%. Elevation of Systemic Vascular Resistance (SVR) could generate lactic acidosis and low cardiac output (High afterload). Hypothermia should also be avoided because it could elevate SVR and VO2.
  - The surgery is usually performed within the first 2 weeks of life. These neonates are usually very sick and in order for systemic circulation to get oxygenated blood, there must be an open atrium as well as a PDA. This can be done with an atrial septectomy and PGE.

CONGENITAL CARDIAC PROCEDURES

NORWOOD (CONTINUED)

- Brief Surgical Description: A new aorta is created using the pulmonary artery in conjunction and amalgamation with whatever viable aortic tissue can be utilized. There is now no pulmonary blood flow d/t utilization of the PA for the neoaorta. This is alleviated with an aortopulmonary shunt; a BT (Blalock-Taussig) shunt is placed from an artery (usually the Inominate) directly to the RPA, another option is a Sano shunt which is larger and goes directly from the ventricle to the pulmonary artery.



CONGENITAL CARDIAC PROCEDURES

BI-DIRECTIONAL GLENN (Stage 2 for Single Ventricle Physiology)

- Concomitant Disorders:
  - Hypoplastic Left Heart Syndrome
  - Pulmonary Atresia with Intact Ventricular Septum
  - Tricuspid Atresia

- Position: Supine/Lateral

- Surgical Time: 4-8 hours

- Anesthesia Management: General Anesthesia with Cardiopulmonary Bypass

- Post-Op: Inpatient, Straight to ICU

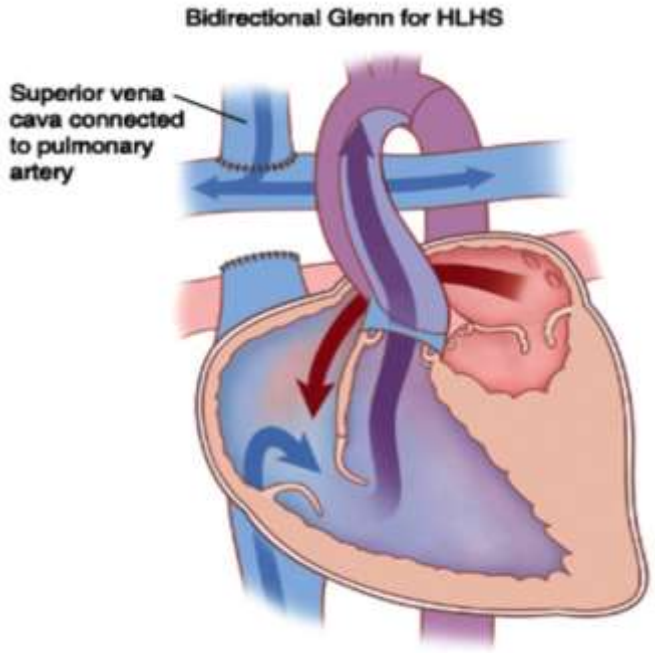
- Special Considerations:

  - After the surgery is finished, **return to spontaneous breathing as soon as possible** is beneficial as flow through the cavopulmonary anastomosis is limited by mechanical ventilation and PEEP.
  - Passive hypercapnia in the 45-50 ETCO2 is acceptable at this point as it promotes Glenn flow and can actually decrease the amount of lactic acid buildup.
  - Remember, pulmonary blood flow is PASSIVE now, **avoid measures that increase PVR** such as hypercapnia in the 50+ ETCO2 range and hypoxia.
  - Utilize appropriate pain management strategies to reduce pain and crying as these can limit pulmonary blood flow
  - Venous congestion is common as the body accommodates, **keep the head midline and elevated** to prevent occlusion of the IJ's and promote venous drainage.

CONGENITAL CARDIAC PROCEDURES

BI-DIRECTIONAL GLENN CONTINUED

- Brief Surgical Description: The second stage of surgical procedures for single ventricle physiology is referred to as the Glenn (Bi-Directional Glenn) procedure. During the procedure the previous shunt providing pulmonary blood flow will be taken down and pulmonary blood flow will now be provided passively by connecting the SVC directly to the pulmonary artery. At this point, the ventricle pumps blood to the body and the bottom half drains back to the heart while the top half of the body will drain directly to the lungs picking up oxygenated blood. Saturations will generally be in the 75%-85% range at this point.



CONGENITAL CARDIAC PROCEDURES

FONTAN PROCEDURE (Stage 3 for Single Ventricle Physiology)

- Concomitant Disorders:
  - Hypoplastic Left Heart Syndrome
  - Pulmonary Atresia with Intact Ventricular Septum
  - Tricuspid Atresia

- Position: Supine/Lateral

- Surgical Time: 4-8 hours

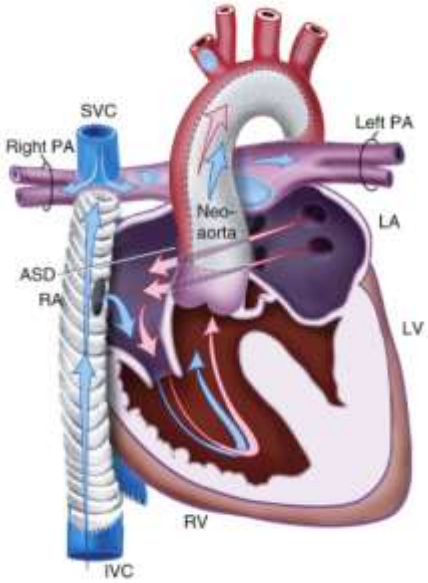
- Anesthesia Management: General Anesthesia with or without Cardiopulmonary Bypass

- Post-Op: Inpatient, Straight to ICU

- Special Considerations:

  - PVR must remain low, avoid hypercarbia and/or hypoxia d/t dramatic decreases in pulmonary blood flow
  - Saturations will usually not be 100% d/t a fenestration in the conduit and the right atrium, this allows excessive pulmonary pressures to vent to systemic circulation and provides a means of arterial/venous mixing
  - ALL pulmonary blood flow is now drainage dependent and hence PVR controls pulmonary blood flow and the amount of oxygenated blood reaching systemic circulation

- Brief Surgical Description: The IVC is connected to the pulmonary circulation, completing the closed circuit. This can be accomplished via an extracardiac or intracardiac conduit which essentially extends and connects the IVC to provide a secure cavopulmonary anastomosis. At this point the single ventricle pumps only to the body, ALL venous drainage is now to the lungs providing two separate circuits and restoring the body back to its original 2 circuit physiology.



CONGENITAL CARDIAC PROCEDURES

TETRALOGY OF FALLOT (MOST COMMON CYANOTIC DEFECT)

- Concomitant Disorders:
  - VSD
  - Overriding aorta
  - RV outflow obstruction
  - RV hypertrophy
- Position: Supine/Lateral
- Surgical Time: 4-8 hours
- Anesthesia Management: General Anesthesia with or without Cardiopulmonary Bypass
- Post-Op: Inpatient, Straight to ICU
- Special Considerations:
  - This disease can be initially palliated or a complete repair can be done, if a simple shunt is placed to bypass the RVOTO, CPB is usually not required and the case is relatively short. If complete repair of all defects ensues, CPB is required and the case is significantly longer.
  - Central and arterial access (If only shunt, place A-line opposite arm of shunt)
  - Mitigate crying/stress to avoid hypercyanotic episodes
  - Inhalational or IV induction
  - Milrinone helps provide inotropy and lusitropy
  - Excessive inotropes may worsen RVOTO
  - JET is common post-op d/t stretching of atria, avoid pyrexia and excessive beta stim as these trigger JET
  - RV dysfunction and Pulmonary regurgitation can occur post-op
  - RV pressure measurements help assess quality of the repair

CONGENITAL CARDIAC PROCEDURES

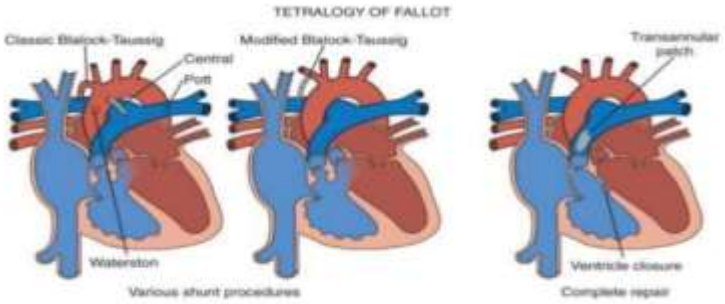
TETRALOGY OF FALLOT CONTINUED

TET SPELL AKA HYPERCYANOTIC SPELL

- Rapid desaturation and systemic compromise
    - Remember that these children have an obstruction from the RV to the PA as well as a VSD, this means that anything that narrows the outflow tract or increases PVR can cause excessive blood to be shunted across the VSD from Right to Left severely limiting pulmonary blood flow.

- Interventions for TET Spell
    - Phenylephrine 0.5-1 mcg/kg
    - Norepi 0.5 mcg/kg bolus followed by 0.01-0.2 mcg/kg/min
    - 100% O2 with Hyperventilation
    - IV fluid bolus 10-20 ml/kg
    - Fentanyl 1 -2 mcg/kg or Morphine 0.1-0.3 mg/kg.
    - Propanolol 0.1-0.3 mg/kg bolus (Relaxes infundibulum)
    - Bring legs to chest and/or have the child squat

- Brief Surgical Description: The RVOTO is palliated with a transannular patch or infundibulectomy and/or both. The VSD is patched. A shunt can also be placed for temporary palliation.



GENERAL CONGENITAL CARDIAC CONSIDERATIONS

Classification of CHD:

- Simple **Left to Right**: Increased Pulmonary Blood Flow (**Acyanotic** Defect)
  - **Atrial Septal Defect (ASD)**
  - **Ventricular Septal Defect (VSD)**
  - **Patent Ductus Arteriosus (PDA)**
  - Endocardial cushion defect (Atrioventricular septal defect (AVSD)
  - Aortopulmonary window (AP window)

- Simple **Right to Left:** Decreased Pulmonary Blood Flow (**Cyanotic** Defect)
  - **Tetralogy of Fallot (TOF)**
  - **Pulmonary Atresia**
  - **Tricuspid Atresia**
  - Ebstein Anomaly

- Complex Shunts: Mixing of Pulmonary and Systemic Blood Flow with Cyanosis
  - **Transposition of the great arteries (TGA)**
  - **Truncus Arteriosus**
  - Total anomalous pulmonary venous connection (TAPVC)
  - Double-outlet right ventricle (DORV)
  - **Hypoplastic left heart syndrome (HLHS)**

- Obstructive Lesions:
  - Aortic Stenosis
  - Mitral Stenosis
  - Pulmonary Stenosis
  - Coarctation of aorta
  - Interrupted aortic arch

GENERAL CONGENITAL CARDIAC CONSIDERATIONS

General Pearls

- Physical Examination:
  - Failure to thrive
  - Difficult feeding
  - Breathlessness
  - Recurrent chest infection
  - Tachycardia
  - Cardiac murmur
  - Hepatomegaly
  - Cardiomegaly
  - Pulmonary plethora
  - Wheezing

- Common Considerations:
  - **Avoid air bubbles** in tubing d/t possible arterial embolus
  - **Avoid 100% 02**, have AIR available for transport
  - One of the only pediatric situations where bradycardia may not be airway induced, do not hyperventilate if you do not know the disease process

- Common Congenital Associations with Cardiac Anomalies:
  - **VACTERL**: **V**ertebral anomalies, **A**nal atresia, **C**ardiac defect, **T**racheo**E**sophageal atresia, **R**enal anomalies, & **L**imb abnormalities.
  - **CHARGE**: **C**oloboma of the eye, **H**eart defects, **A**tresia of the choanae, **R**etardation of growth and development, **G**enitourinary defects, & **E**ar anomalies.
  - **CATCH-22** (mnemonic for DiGeorge syndrome): **C**ardiac defect, **A**bnormal facies, **T**hymic hypoplasia, **C**left palate, **H**ypocalcemia & **22**q11 chromosome microdeletion.

PEDIATRIC MEDICATIONS

RESUSCITATION

OXYGEN	Ventilate with 100% Oxygen
EPINEPHRINE	1 mcg/kg IV to treat hypotension; 10 mcg/kg IV for cardiac arrest; repeat every 3-5 mins as needed
ATROPINE	20 mcg/kg IV for symptomatic bradycardia; max dose is 1 mg for child and 2 mg for adolescent
BICARBONATE	1-2 mEq/kg IV to be guided by ABG analysis
CALCIUM CHLORIDE	10-20 mg/kg IV
CALCIUM GLUCONATE	30-60 mg/kg IV
ADENOSINE	100 mcg/kg rapid IV bolus with flush (Max is 6mg); second dose 200 mcg/kg (Max is 12 mg) *Reduce dose by half if given through a central line and in patients with prior heart transplantation.
LIDOCAINE	1 mg/kg IV followed by 20-50 mcg/kg/min by infusion pump
AMIODARONE	5 mg/kg IV (Max 300 mg for V-FIB & V-TACH)
PROCAINAMIDE	5-15 mg/kg IV loading dose over 30-60 mins, then 20-80 mcg/kg/min by infusion pump, ECG monitoring required. Caution: hypotension and prolonged QT interval may occur particularly when combined with amiodarone
MAGNESIUM	25-50 mg/kg IV for Torsades de Pointes (Max 2 grams)

PEDIATRIC MEDICATIONS

VASOACTIVE

DOPAMINE	1-20 mcg/kg/min; titrate to effect
DOBUTAMINE	1-20 mcg/kg/min; titrate to effect
EPINEPHRINE	0.1-1 mcg/kg/min; titrate to effect
ISOPROTERENOL	0.1-1 mcg/kg/min; titrate to effect
NOREPINEPHRINE	0.1-1 mcg/kg/min; titrate to effect
PHENYLEPHRINE	0.1-1 mcg/kg/min; titrate to effect
MILRINONE	50-100 mcg/kg loading dose followed by 0.25-1 mcg/kg/min infusion
NITROPRUSSIDE	0.5-10 mcg/kg/min; titrate to effect; observe for signs of cyanide toxicity
NITROGLYCERINE	1-10 mcg/kg/min; titrate to effect
PROSTAGLANDIN E1	0.01-0.1 mcg/kg/min (Apnea may occur and intubation is usually required with doses > 0.05 mcg/kg/min)
VASOPRESSIN	0.0001-0.001 units/kg/min

CARDIOVERSION/DEFRIBRILLATION (EXTERNAL)

CARDIOVERSION	For Supraventricular and Ventricular tachycardia 0.5 joules/kg **SYNCHRONOUS**; repeat up to 2 joules/kg
DEFRIBRILLATION	For Ventricular fibrillation/ Ventricular tachycardia 2 joules/kg **ASYNCHRONOUS**; repeat up to 4 joules/kg

PEDIATRIC MEDICATIONS

NEUROMUSCULAR BLOCKING AGENTS

SUCCINYLCHOLINE	2-3 mg/kg IV for < 1 year; 1-2 mg/kg IV; 4-5 mg/kg IM or 1-3 mg/kg intralingual (submental) for > 1 year.
ROCURONIUM	0.3 mg/kg in neonates = ~ 30-45 min duration, 0.6 mg/kg in children = ~ 30-45 min duration, 1.2 mg/kg for RSI = ~ 75 min duration
VECURONIUM	0.1 mg/kg IV
PANCURONIUM	0.05-0.1 mg/kg IV
CISATRACURIUM	0.1 mg/kg IV neonates; 0.1-0.2 mg/kg older children
ATRACURIUM	0.5 mg/kg IV

REVERSAL AGENTS

NEOSTIGMINE	0.02-0.05 mg/kg
EDROPHONIUM	0.3-1 mg/kg
SUGAMMADEX	2-16 mg/kg based on TOF
PHYSOSTIGMINE	0.01-0.03 mg/kg followed by 0.03 mg/kg/hr to treat cholinergic syndrome
NALOXONE	0.25-0.5 mcg/kg, additional doses as needed; up to 100 mcg/kg (Max 2 mg) may be needed for respiratory arrest, may be given IM
FLUMAZENIL	10 mcg/kg/dose; titrate to effect; must observe child for a minimum of 2 hrs after antagonism
ATROPINE	0.02 mg/kg
GLYCOPYRROLATE	0.01 mg/kg

PEDIATRIC MEDICATIONS

INDUCTION AGENTS

ROUTE	IV (mg/kg)	IM (mg/kg)	PR (mg/kg)
PROPOFOL	2-3		
KETAMINE	1-2	3-12	5-10
ETOMIDATE	0.2-0.3		
THIOPENTAL	4-6		20-30
METHOHEXITAL	1-3		20-30

MIDAZOLAM

ROUTE	Mg/Kg	Onset (mins)	Peak Effect (mins)
IV	0.05-0.15	Immediate	3-5
IM	0.1-0.2	3-5	10-20
Orogastric	0.25-0.75	5-15	10-30
Nasal	0.1-0.2	3-5	10-15
Rectal	0.75-1	5-10	10-30

KETAMINE

ROUTE	Mg/Kg
IV	1-2
IM	2-10
Orogastric	3-6
Nasal	2-4
Rectal	5-10

SEDATIVES

CHLORAL HYDRATE	50-100 mg/kg, Max 2 grams in divided doses (PO or PR)
DEXMEDETOMIDINE	0.3-2 mcg/kg loading dose over 10 mins, followed by 0.7-1 mcg/kg/hr
PENTOBARBITAL	2 mg/kg IV every 10 mins up to 6 mg/kg

PEDIATRIC MEDICATIONS

ANALGESICS

NON-OPIOID

ACETAMINOPHEN	PO: 10-15 mg/kg every 4-6 hrs PR: 30-40 mg/kg loading dose followed by 20 mg/kg every 6 hrs IV: 15 mg/kg every 6 hrs
IBUPROFEN	10 mg/kg PO every 6 hrs (Max 800 mg)
KETOROLAC	< 50 kg: 0.5 mg/kg up to 15 mg >50 kg: 0.5 mg/kg up to 30 mg Dose is the same for IV, IM & PO and is every 6 hours
KETAMINE	0.25-1 mg/kg every 8-10 mins IV as needed

OPIOID

FENTANYL	0.5-2 mcg/kg IV; up to 100 mcg/kg for cardiac and other major cases
MORPHINE	0.05-.1 mg/kg IV every 3-4 hrs; post-op analgesia infusion at 5-20 mcg/kg/hr
HYDROMORPHONE	0.015 mg/kg IV every 3-4 hrs
REMIFENTANIL	0.05-0.15 mcg/kg/min
CODEINE	0.5-1.5 mg/kg PO/IM every 6 hrs

ANTIEMETICS

ROUTE	IV (mg/kg)	PO (mg/kg)
Dexamethasone	0.0625-0.15 (Max 10-15 mg)	
Metoclopramide	0.15	0.15
Ondansetron	0.05-0.1 up to 4 mg Max	0.1 up to 4 mg
Tropisetron	0.1-0.2	

PEDIATRIC MEDICATIONS

INTRAVENOUS ANTIBIOTICS

ANTIBIOTIC (IV)	1ST week postnatal (>2 kg)	1-4 weeks postnatal	>4 weeks postnatal
AMPICILLIN	50 mg/kg Q8 hrs	25-50 mg/kg Q6 hrs	25-50 mg/kg Q4-6 hrs
AMPICILLIN/SULBACTAM (UNASYN)			25-37.5 mg/kg Q6 hrs
CEFOTAXIME (CLAFORAN)	50 mg/kg Q8-12 hrs	50 mg/kg Q6-8 hrs	50 mg/kg Q6-8 hrs
CEFAZOLIN (ANCEF)	20 mg/kg Q12 hrs	20 mg/kg Q8 hrs	16-33 mg/kg Q8 hrs 3 gm max
CEFTRIAXONE (ROCEPHIN)	50 mg/kg Q24 hrs	50-75 mg/kg Q24 hrs	50-75 mg/kg Q12-24 hrs
CEFUROXIME (ZINACEF)	25-50 mg/kg Q12 hrs	25-50 mg/kg Q12 hrs	25-50 mg/kg Q8 hrs
CLINDAMYCIN (CLEOCIN)	5 mg/kg Q8 hrs	10 mg/kg Q8 hrs	10 mg/kg Q6-8 hrs
GENTAMICIN (Monitoring blood levels recommended)	4 mg/kg Q24 hrs	4 mg/kg Q24 hrs	2-2.5 mg/kg Q8 hrs
METRONIDAZOLE	7.5 mg/kg Q12 hrs	15 mg/kg Q12 hrs	7.5 mg/kg Q6 hrs
NAFCILLIN (UNIPEN)	25 mg/kg Q8 hrs	25 mg/kg Q6 hrs	25-50 mg/kg Q6 hrs
PIPERACILLIN/TAZOBACTAM (ZOSYN)			37.5-75 mg/kg Q6 hrs
TICARCILLIN (TIMENTIN)	75 mg/kg Q8 hrs	50-75 mg/kg Q6 hrs	33-50 mg/kg Q4 hrs
VANCOMYCIN (VANCOCIN) (Monitoring blood levels recommended)	15 mg/kg Q12 hrs	15 mg/kg Q8 hrs	10-15 mg/kg Q8 hrs

CLINICAL PEARLS

RULE OF SIXES

0.1 mcg/kg/min = 0.6 mg/100mL given as (kg) in mL/hr
1 mcg/kg/min = 6 mg/100mL given as (kg) in mL/hr
10 mcg/kg/min = 60 mg/100mL given as (kg) in mL/hr
20 mcg/kg/min = 120 mg/100mL given as (kg) in mL/hr

ANAPHYLAXIS

Oxygen	Ventilate with 100% Oxygen
Epinephrine	1 mcg/kg IV to treat hypotension/bronchospasm; repeat every 3-5 mins as needed; consider continuous infusion
Fluid Bolus	20 mL/kg balanced salt solution; repeat as needed
Phenylephrine	0.1 mcg/kg/min IV; titrate to effect if inadequate response to epinephrine
Hydrocortisone	2-3 mg/kg IV
Diphenhydramine	1-2 mg/kg IV
Ranitidine	1.5 mg/kg IV

HYPERKALEMIA TREATMENT

Calcium chloride	5-10 mg/kg/dose IV	
Calcium gluconate	15-30 mg/kg/dose IV	
Hyperventilation	**Albuterol** (Inhalation)	**Salbutamol** (5 ug/kg IV over 15 mins)
Glucose + Insulin	**Glucose**(0.5-1g/kg) + **Insulin** (0.1U/kg) over 30-60 mins	
Kayexalate	1 g/kg (up to 40g) q4hr (PO, PR)	

CLINICAL PEARLS

SPECIAL PROBLEMS

Diabetes Insipidus
Dilute polyuria (urine osmolality <250 mOsm/L, >2 ml/kg/hr, hypernatremia (sodium > 145 mEq/L) with serum hyperosmolality (>300 mOsm/L)
DDAVP (desmopressin) 1-10 mU/kg/hr (0.0025-0.025 mcg/kg/hr), titrate to effect (4 mcg = 16 IU)

Von Willebrand Disease (VWD)
DDAVP (desmopressin) 0.3 mcg/kg IV once given 30 mins preoperatively
Amicar 100mg/kg IV or PO 1 hour preoperatively, then every 4-6 hours depending on the type of VWD

SUBACUTE BACTERIAL ENDOCARDITIS REGIMEN FOR DENTAL SURGERY

Oral	Amoxicillin 50mg/kg PO
IV (unable to take PO meds)	Ampicillin, Cefazolin, or Ceftriaxone 50 mg/kg IV
Oral (allergy to penicillins)	Cephalexin 50 mg/kg or Clindamycin 20 mg/kg or Azithromycin 15mg/kg PO
IV (allergy to penicillins & unable to take PO	Cefazolin or Ceftriaxone 50 mg/kg or Clindamycin 20mg/kg IV

CLINICAL PEARLS

AIRWAY

LARYNGEAL MASK AIRWAY

Weight (kg)	Size	Cuff Volume	Largest ETT that will fit through LMA
<5	1	4	3.5 uncuffed
5-10	1.5	7	4 uncuffed
10-20	2	10	4.5 uncuffed
20-30	2.5	14	5 uncuffed
30-50	3	20	6 cuffed
50-70	4	30	6 cuffed
70-100	5	40	7 cuffed
>100	6	50	7 cuffed

LARYNGOSCOPE BLADES (APPROXIMATE SIZE)

Weight (kg)	Miller	Wis-Hipple	Macintosh
Preterm	0		
Full-term	0		
Term- 2 years	1	1	
2-6 years		1.5	1-2
6-10 years	2	NA	2
>10 years	2 or 3	NA	2 or 3

CLINICAL PEARLS

AIRWAY

ETT SIZE

	Uncuffed	Cuffed
Preterm (<1.5 kg)	2.5	
Preterm (1.5-3 kg)	3	
Full-term neonate	3	
1 year	4	3-3.5
2 years	5	4-4.5
>2 years	Age/4 + 4 or (4.5)	0.5-1.0 smaller than uncuffed ETT

DISTANCE OF INSERTION (Cm) WITH GUMS

Preterm (<1000 grams)	6-7
Preterm (<2000 grams)	7-9
Full-term neonate	~10
1 year	~11
2 years	~12
16 years	~18
>= 20 years	~20-21

CLINICAL PEARLS

ANATOMIC AND PHYSIOLOGIC DIFFERENCES

AIRWAY ANATOMY

1. Classically it has been taught that the narrowest portion of the infant's larynx was at the cricoid ring. New studies utilizing advanced imaging via MRI, CT, and direct bronchoscopic visualization are showing that the narrowest portion is at the glottic opening and the sub-vocal cord level.

2. The shape of the pediatric larynx is elliptical in shape rather than the classically taught conical shape, with an A-P diameter longer than the transverse diameter. The importance of this lies in the use of a cuffed vs. uncuffed tube. If one utilizes an uncuffed tube and relies on the absence of a leak to determine the size of uncuffed ETT there may be significant pressure placed on the areas lateral to the tube relative to the areas anterior and posterior to the tube. This is why cuffed ETT's are becoming more and more popular.

3. Position of larynx is more cephalad (C3-4) in pediatric patient vs adult (C4-5).

4. Epiglottis is flat and broad in an adult with an axis that is parallel to the trachea versus an infant's epiglottis which is narrow and omega shaped with an axis angled away from the trachea… one reason why a straight blade is often superior to a curved blade in visualizing the glottis.

5. Axis of an adult's vocal cords is perpendicular to the trachea, but in an infant it is angled. This can make the insertion of the ETT more difficult as advancement can become hindered by the anterior commissures of the vocal folds.

6. By age 10 there is no difference between the adult and child's larynx.

CLINICAL PEARLS

ANATOMIC AND PHYSIOLOGIC DIFFERENCES

RESPIRATORY PHYSIOLOGY

1. Do not have the amount of functioning alveoli as an adult until 8 years of life.
2. Infants are at high risk for respiratory failure, why?
    a. Work of breathing is greatly increased in infants because of unfavorable rib alignment (horizontal instead of angled as in an older child/adult).
    b. Respiratory fatigue due to much less type 1 muscle fibers which are slow twitch and have high oxidative capacity
    c. Chest wall compliance is much higher than adults, which decreases its ability to spring out… this brings FRC close to closing capacity.
    d. Closing capacity= lung volume at which alveoli and small airways begin to collapse.
    e. O2 consumption at rest is twice (6-8 ml/kg) that of an adult.
    f. So use PEEP!

3. Hypoxia and hypercarbia DEPRESS respiration in neonates (opposite in adults)

4. Response to hypoxia is biphasic in neonates
    a. Initially hypoxia causes hyperpnea (lasts 2 minutes) and then respiratory depression.
    b. The initial hyperpnea response is abolished in neonates that are hypothermic or have low levels of anesthetic gas on board.

5. Obilgate nasal breathers as neonates, but ~40% of full-term infants can switch to oral breathing if their nares become obstructed compared to ~8% of pre-term infants born at 31-32 weeks post-conception

CLINICAL PEARLS

ANATOMIC AND PHYSIOLOGIC DIFFERENCES

CARDIAC PHYSIOLOGY

	IMMATURE MYOCARDIUM	ADULT MYOCARDIUM
Cytoarchitecture	1. Fewer mitochondria and SR 2.Poorly formed T tubules 3.Limited contractile elements and increased water content 4.Dependence on extracellular calcium for contractility	1. Organized mitochondrial rows, abundant SR 2. Well-formed T tubules 3.Increased number of myofibrils with better orientation 4.Rapid release and reuptake of calcium via SR
Metabolism	1.Carbohydrates and lactate as primary energy sources 2. Increased glycogen stores and anaerobic glycolysis for ATP 3.Decreased nucleotidase activity, retained ATP precursors 4.Better tolerance to ischemia with rapid recovery of function	1.Free fatty acids as primary source for ATP 2.Limited glycogen stores and glycolytic function 3.Increased 5-nucleotidase activity, rapid ATP depletion 4.Less tolerance to ischemia
Function	1.Decreased compliance 2.Limited CO augmentation with increased preload 3.Decreased tolerance to afterload 4.Immature autonomic innervation: PSNS > SNS. SNS incomplete	1.Normally developed tension 2.Able to improve CO with increased preload and to maintain CO with increasing afterload

CLINICAL PEARLS

ANATOMIC AND PHYSIOLOGIC DIFFERENCES

CARDIAC PHYSIOLOGY

HEMODYNAMIC CHANGES AT BIRTH

RIGHT VENTRICLE	LEFT VENTRICLE
Decreased afterload	Increased afterload
Decreased PVR	Placenta eliminated
Ductal closure	Ductal closure
Decreased volume load	Increased volume load
Eliminated umbilical vein return	Increased pul venous return
Output diminished 25%	Ouput increases ~50%
	Transient L→R shunt at PDA

TRANSITION FROM FETAL TO NEONATAL CIRCULATION