Pediatric PFTs- Special Considerations and Cases

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Learning Objectives:

- Review ***major indications*** for performing PFTs on pediatric patients
- Examine ***special considerations*** for performing PFTs in the pediatric population
- Review ***selected cases studies in pediatric PFTs***
- Provide ***additional key resources***

Indications-Why Perform PFTs on Pediatric and other Young Patients?

- Some are similar to indications in adults.
  - Identify the presence of and severity of obstruction and restrictive disorders
  - Progression of disease state via serial PFTs
  - Response to therapy
- Also provides important data on lung growth.

Special Considerations: *Infants and Young Toddlers*

- Not capable of following directions.
- Generally require the infant to be sedated.
  - A formal and sedation protocol should be established.
  - An anesthesiologist is generally present, especially in less stable patient requiring IV sedation.
    - Narcotics (secobarbital)
- Toddlers may be sedated with an oral agent such as Chloral hydrate (CH).
  - 50-75 mg/kg
  - Feedings held for 4-6 hrs before CH administration
- Therefore, the need for testing should be pervasive.
- Monitoring should be vigilant and there should be awareness that apnea or loss of a patient airway is possible with sedation.
- Rescue protocols must be in place, including having a crash cart nearby.

Special Considerations (Cont)

- Infants (Up to one year)
  - ***Lung compliance*** can be measured via Passive Occlusion Technique.
    - Change in Volume / Change in Pressure
  - Hering-Breuer Reflex accounts for infants up to 1 year to hold their breath when their A/W is occluded.
  - During a single breath occlusion, alveolar pressure can be measured via a pressure transducer.
  - When the valve opens, the infant passively exhales and volume can be measured.
  - A/W Resistance can be measured from the same maneuver.

- Toddlers (2 ½ - 3 years)
  - Chest Wall become more rigid.
  - Hering-Breuer Reflex is lost, therefore passive occlusion technique may not be possible
  - However, they may be able to follow basic instructions.
  - They also may be able to tolerate simple passive procedures without the need for sedation.

Special Considerations: Children Over 3 years old

- Children as young as 3 years old have the potential to perform spirometry (up to 50% can perform basic spirometry).
- Trust must first be gained by the clinician.
- Nose clips are a must!
- With appropriate training, introducing spirometry to children as young as 3-5 years old can yield remarkable results.
  - Practice blowing on a pinwheel
- The biggest challenge in pre-school children is maintaining exhalation after the initial blast.
- ATS Focus Group Recommendations include the following:
  - Identify premature termination by comparing flow at termination to peak flow
  - Report the highest FVC & FEV1
  - Due to small lungs, extrapolated volume may exceed the 5% (or 50 ml) ATS Guideline and values as high as 80 mls or 12.5% may be acceptable.
- By age 5, on average, most children can perform spirometry with adequate technique and repeatability.

What Conditions/Diseases Warrant PFT's in Children?

- Asthma
- Cystic Fibrosis
- Neuromuscular Diseases- e.g., Spinal Muscular Atrophy
- Others:
  - S/P Bronchopulmonary Dysplasia
  - Vocal Cord Dysfunction
  - Bronchiolitis Obliterans
  - Pulmonary Fibrosis

Case 1: Cystic Fibrosis

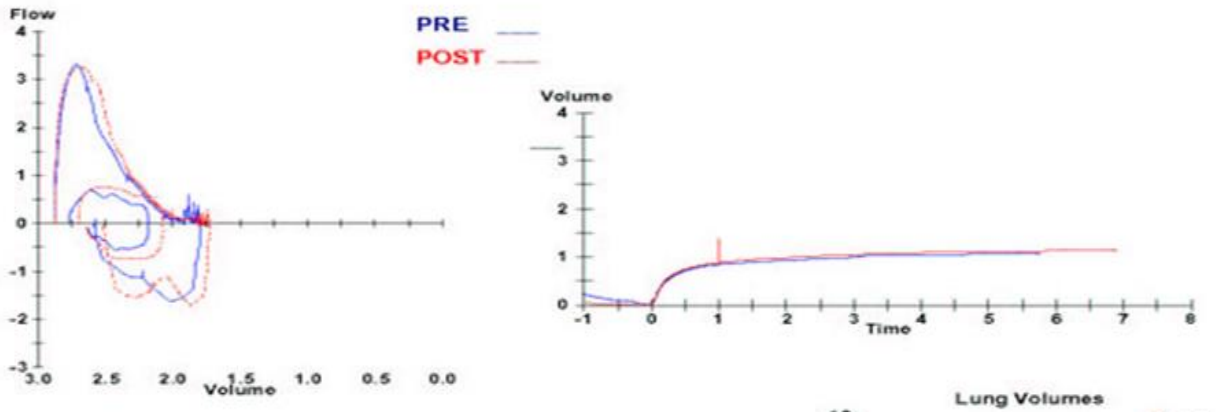
- An 8 YO boy has been seen at a CF center since the diagnosis, and spirometry has been routinely performed at every clinic visit. A complete set of PFTs is obtained annually, including lung volume determination.

Case 1: Recent PFT Results

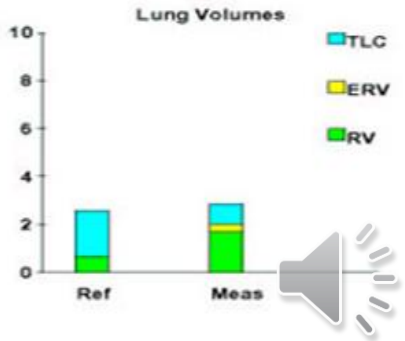
Spirometry		PRED	CI	PRE-RX BEST	PRE-RX %PRED	POST-RX BEST	POST-RX %PRED	% CHG
FVC	Liters	1.84	0.31	1.09	59	1.15	63	6
FEV1	Liters	1.60	0.28	0.89	56	0.88	55	-1
FEV1/FVC	%	87	10	82		76		
FEF25-75%	L/sec	1.89	0.61	0.74	39	0.72	38	-3
PEF	L/sec	3.66	1.03	3.37	92	3.25	89	-4
FIVC	Liters			0.80		0.79		-1
FEF/FIF50		<1.00		0.90		0.73		-19
FVL ECode				000011		000000		
FET100%	Sec			5.75		6.88		20

Calibration: Prod Volume: 3.00 Liters, Flow Cal Date: 02/12/03; Inspire Avg: 3.03, Expire Avg: 3.03; PF Reference: Dockery/Zapletal/Morris

Pulse Ox: SaO2 96.0 %



Lung Volumes		PRED	PRE-RX	% PRED
VC	Liters	1.84	1.17	63
TLC	Liters	2.59	2.88	111
FRC PL	Liters	1.25	2.04	163
RV	Liters	0.66	1.71	258
RV/TLC	%	26	60	
IC	Liters		0.84	
ERV	Liters		0.29	



Case 1: Question 1

- What information does the spirometry alone provide?
  - There is a proportionate and moderate decrease in both the FVC and FEV1.
  - The ratio of FEV1/FVC is within the normal range.
  - Additionally, the FEF25% to 75% is decreased to a greater degree than the FVC and FEV1. The “tailing end” of the FV loop is a clue to the airflow obstruction at lower lung volumes.
  - CF is a disease process that results in progressive and significant airway obstruction.
  - Note that the degree of obstruction in the small, peripheral airways can be profound.

Case 1: Question 2

- What additional information is revealed by the lung volume determination?
  - This subject's lung volume measurements by body plethysmography rule out any thoughts of a restrictive disorder.
  - The TLC is normal (not restricted), and the FRC, RV, and RV/TLC suggest significant air trapping.
  - The combination of reduced FVC, FEV1, and yet substantially elevated RV is a concerning finding in an 8-year-old with CF.
  - Furthermore, lack of improvement post-bronchodilator suggests little to no reactive airway component.
  - Note: Sometimes, subjects with CF will improve after bronchodilator with aggressive coughing due to mobilization of secretions.

Case 1: Questions 3 & 4

3. Does the spirometry meet all ATS criteria for acceptability?
   - Examination of the pre-bronchodilator volume–time graph indicates that strict ATS criteria were not reached.
   - The subject's expiratory time did not reach 6 sec, and a clear flow plateau may not have been reached.
   - Although ATS criteria are important goals, small children may not be able to achieve all the criteria. Repeatability of efforts is critical, but a 6-second expiratory time and a flow plateau are not essential in interpreting this PFT.

4. What is the final interpretation of this PFT?

A symmetric and moderate reduction in FEV1 and FVC without a response to a bronchodilator.

The TLC is normal; however, RV and RV/TLC are significantly elevated, which suggests air trapping and intrathoracic airflow obstruction.

Oxygen saturation on room air is borderline normal but adequate.

Case 2: Severe, Persistent Asthma

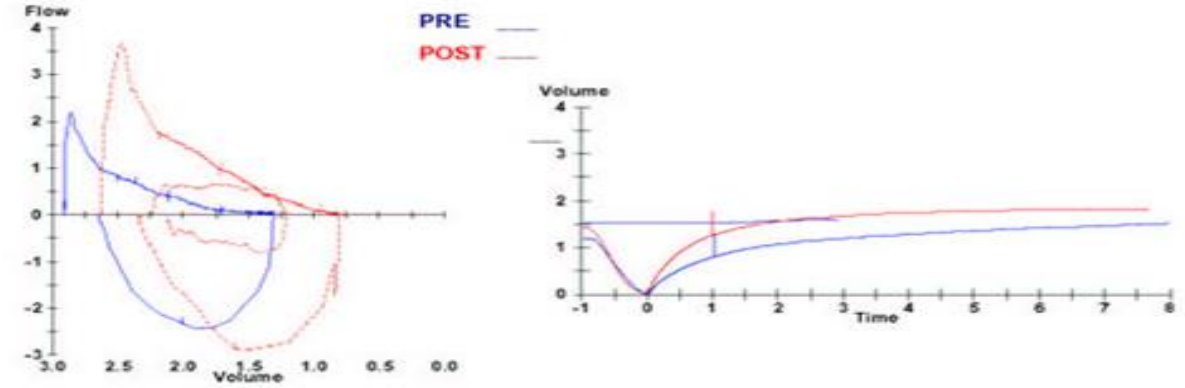
- A 9-year-old girl has been treated for severe, persistent asthma since she was a young child. Her asthma medication regimen includes Singulair, Advair, albuterol (PRN), and Flonase. She occasionally requires prednisone during acute exacerbations. She also has been hospitalized on several occasions, including admissions to the PICU. This child is notable in that she has rarely been known to wheeze or have any asthma symptoms during clinic visits. The following PFTs are typical of her routine clinic visits.

Case 2: Recent PFT Results

Spirometry		PRED	CI	PRE-RX BEST	PRE-RX %PRED	POST-RX BEST	POST-RX %PRED	% CHG
FVC	Liters	1.77	0.33	1.60	90	1.82	103	14
FEV1	Liters	1.55	0.29	0.80	52	1.26	81	58
FEV1/FVC	%	88	9	50		69		
FEF25-75%	L/sec	1.96	0.65	0.29	15	0.84	43	193
PEF	L/sec	4.29	1.21	2.22	52	3.75	87	69
FIVC	Liters			1.34		1.54		15
FEF/FIF50				0.17		0.34		99
FVL ECode				001010		000000		
FET100%	Sec			9.88		7.65		-23

Calibration: Pred Volume: 3.00 Flow Cal Date: 01/27/00 Inspire Avg: 3.01 Expire Avg: 2.98 PF Reference: Dockery/Zap/Morris-Black

Pulse Ox: SaO2 95.0 %



Lung Volumes		PRED	PRE-RX	PRE-RX% PRED	POST RX	POST RX% PRED	% CHG
VC	Liters	1.77	1.76	99	1.86	105	6
TLC	Liters	2.57	2.91	113	2.63	102	-10
FRC PL	Liters	1.26	1.64	130	1.32	105	-20
RV	Liters	0.67	1.15	172	0.77	115	-33
RV/TLC	%	25	39		29		
IC	Liters		1.26		1.31		
ERV	Liters		0.41		0.57		

Case 2: Question 1

1. How should the spirometry and lung volume measurements before the bronchodilator be interpreted?

- The pre-bronchodilator spirometry indicates moderate intrathoracic airflow obstruction.
- The FV loop is a classic concave, or very “scooped,” expiratory pattern. The FVC is in the normal range; however, the FEV1 and FEV1/FVC are significantly reduced.
- The airflow obstruction is further confirmed with lung volume determination. Note the TLC is at the “higher” end of normal (113% of predicted).
- Significantly, her FRC, RV, and RV/TLC are high. The volume–time graph indicates that the subject’s expiratory time is prolonged at 10 sec.
- Oxygen saturation on room air is adequate but mildly reduced.

Case 2: Question 2

2. What changes are seen after the bronchodilator in spirometry and lung volume measurements, and how are they related to the subject's clinical picture?

- After the bronchodilator, there is a significant, 58% improvement in her FEV1. The FEV1/FVC is also improved; however, it is not normalized.
- Airflow obstruction persists despite maximal bronchodilation.
- There is a shift to the right of the position of the FV loop after the bronchodilator, which shows the reduced TLC and RV.
- Although the medical regimen prescribed to treat her asthma is aggressive, the dramatic response to a bronchodilator calls into question her compliance.
- Subjects who do not feel short of breath, do not wheeze, or do not perceive that they are having any asthma symptoms tend to "forget" to take their medications. They often fail to refill prescriptions when appropriate.
- Repeated visits to the PFT laboratory with similar results suggest that this subject may not be using her medications effectively nor adhering to the treatment plan.

Case 2: Question 3

3. What can be hypothesized concerning the pathophysiologic changes occurring due to long-standing persistent asthma in this child?

- Chronic airway obstruction is an concerning sign in a subject of her age and may indicate that ***remodeling*** of the airways due to the presence and persistence of inflammatory mediators, may well be occurring.
- These chronic changes, especially combined with her questionable adherence to the treatment plan, may indicate that she will have more severe or nonreversible airflow obstruction in the future.

Concluding Thoughts and Take-Home Points

- PFTs can provide valuable clinical data in all patient populations.
- The indications for PFT's in younger patient is somewhat similar to those for older adolescent and adult patients.
- However, there are many special considerations which must be viewed when considering, performing and interpreting PFTs in very young patients.
- Failure to recognize and account for such differences can endanger patients, waste resources and contribute to misdiagnosis and flawed treatment plans.
- Proper consideration of such unique aspects can promote better patient care and enhanced clinical outcomes.
- This short presentation only scratches the surface on the many unique considerations for pediatric PFTs…But we hope it encourages you to learn more in this area!

Selected Resources

- Mottran, CD, **Ruppels's Manual of Pulmonary Function Testing – ed** 12th, 2022.
- Kacmarek, RM, Stoller, J & Heuer AJ, ***Egan's Fundamentals of Respiratory Care***, ed 12th ed, 2021.
- Heuer, AJ, ***Clinical Assessment in Respiratory Care***, ed 8, 2022.
- ATS-PFT Interpretation Guide-2022