Thank you, Dr. Stein and Dr. Drutz, for inviting me to speak today. It's wonderful to be in an environment where I can have the opportunity to say hello to so many old friends.
Objectives

- Delineate decision making in transporting critically ill child
- Review provider obligations throughout the process
- Review common physiologic principles in transport
- Overview of common scenarios of pediatric transport

Hopefully today I'm going to speak a little bit about paradigms of transport, what you as a primary care provider should be thinking about when you choose a transport program to patronize, and what resources are out there, and what should you be thinking about for the child that you choose to transport. I hope to help you delineate some decision-making and responsibilities and review provider obligations throughout the transport process, to review a few common physiologic transport principles that make practicing medicine in a transport environment a dynamic and fun thing to do. It allows me as a pediatric intensivist to bring all of my skills to the forefront, and then on top of it, add a dynamic environment where we may encounter different things, be it ambulance, helicopter, or fixed wing. And then if we have a chance, I'll overview some common scenarios of transport.
Here's a brief slide to start out about the history of the transport process. It dates back to the mid 1800s, when ambulances were drawn by horses in England. In the 1870 siege of Paris, hot air balloons were actually used to evac soldiers from Paris. In 1915 was the first time fixed wing aircraft were used to transport patients. And to me this would be just horrific because they used fixed wing, but they put the patients on litters outside the airplane. So if your injuries didn't kill you, the transport probably did. In the 1950s there was this whole evolution of the "golden hour of transport." That is, triaging patients to a certain area, a regionalized area where they could receive care in an expeditious fashion. The whole concept of a time constraint on transport - for surgical management of transport issues - came to the forefront. In the 1970s we saw a regionalization of transport issues, really trying to funnel children or adults into places that could provide subspecialty care. Within the last twenty years now we've had a proliferation of specialized transport teams including neonatal, obstetric, high risk, trauma, pediatric, just to name a few. And justification of all these subspecialized areas really has come to the forefront. I'm hopefully going to resent a little bit of data that will convince you that a pediatric subspecialty transport team is really worth the extra effort.
Well, how and why should you choose to transport a patient that you're taking care of, either in your clinic, in your local emergency room, or wherever you happen to be giving your care? The most common indication we hear is for a higher level of care. And that might not be that you aren't able. You are perfectly capable of handling whatever this youngster has. But you might not have the personnel behind you. You might not have the nursing resources, the pharmaceutical resources, the radiologic resources to hear whatever that is. You might not be able to have the expertise that you need, a pediatric surgeon, a pediatric neurosurgeon, an epileptologist for seizures. And can you do this all in an expeditious fashion for the patient? They may need exceptional procedures. They may need evaluation for transplant. They may need a cerebral angiogram. Things you cannot provide for them. So those are all easily justifiable reasons. Sometimes we have parental requests for transport. That is, that the parents want to get closer back to their home base. The child was in Boston or the child was in Guatemala and needs to be transported back in because the parents want to get back here. Back transports, or reverse transports, are situations where obviously we are sending children back to their center of origin. This most often occurs in technologically dependent special needs kids who want to get closer back to their home base, and to get them there safely, we can provide a transport team that can do that.
The responsibilities of transport. We like to think of it as a continuum of responsibility from the time you pick up that phone and call us or the receiving institution. But, really, there are different points to this. There's the accepting physician. There's the referring physician. So you as the two physicians have to assume care for this patient. And then the accepting institution has a responsibility to be able to provide those services that you need for your youngster. If you have a youngster in respiratory distress, and you choose to send them to a level 2 institution, but then that child goes on to respiratory failure, and they cannot take care of that child who is intubated, sending them to a level 2 institution might not be the ideal place to take care of that youngster. Likewise, if you're monitoring a child for neurologic deterioration because of their intracranial injury, yet you don't have a neurosurgeon who can handle the sequelae if that child in fact does deteriorate, they are not in the most appropriate place. So don't only think about what the child looks like now; try and forecast what are the paradigms of what's worst case scenario.
The responsibility of the referring physician is where the burden, the legal burden, of transport really lies. Okay. A lot of this came out of COBRA legislation in the mid-eighties, which if you remember is the Comprehensive Omnibus Budget Reconciliation Act, and of that as a subset of the Emergency Medicine Treatment and Active Labor Act. This was really set up to help uninsured and indigent patients not be shuffled institution to institution. The vernacular is "patient dumping." And really a lot of the legal ramifications of transport grew out of this literature. But really it is the responsibility of the referring physician to choose the facility, to choose the safest way for the patient to get there, and to be responsible for the patient until they reach that receiving institution. So really we like to think of it as a continuum. When it comes right down to it, it's on the referring physician's shoulders.
There are different kinds of transport teams. And we talked about this just - I mentioned this earlier. You can have the commercial transport program that will transport anybody who stands still who needs to go anywhere. You can have unit-based teams that are, for example, seated in a neonatal or pediatric intensive care unit, or in an emergency room, that are part of a larger general hospital or pediatric institution. Texas Children's has the advantage of having a neonatal-based intensive care transport team in pediatrics that all comes under the umbrella of intensive care transport team.
You have to choose a team. You have to choose a safe way to get there. Most often if you're thinking about a child that needs transport, car is out of the question. It might be ambulance. It might be helicopter. It might be fixed wing. It is not your responsibility to choose mode per se. It is your responsibility to choose the safest way under the auspices of whose care. Personnel is much more important than mode.
If you look at specialty versus non-specialty teams, what do I mean by that? A specialty team would be a pediatric or neonatal intensive care transport team. A non-specialty team would be a transport team that takes all comers, adults, children, pregnant ladies, babies, neonates, anything that's coming. And the location served, the response time, and the cost will be different by each of those. And you have to think about accessibility and expertise. What are you trying to accomplish for your patient? Often it will be limited by the resources available to you in your area. And I encourage you to become familiar with what's available to you before you're faced with a sick child in your office or in your facility.
When you think about children, one of the fastest things you want to do is, get this kid out of my care fast. Get them to where they need to be. But throwing them in an ambulance with an EMT provider or a paramedic might not be a reasonable thing to do. The child is almost always safer in a fixed institution where you can call in experts than out on a city highway. So think about what you've got. This just shows what pre-hospital providers have in the way of education. And even though an EMT and a paramedic have 110 and a thousand hours respectively of education, look at the small proportion of pediatrics. Even a paramedic has less than two working days of pediatric experience. So these people are just as scared of the pediatric population as you are. It's variable, and some paramedics have extensive pediatric experience. But by law, this is all they are required to have.
Well, when you call a pediatric specialty team, what are you going to get? Most often you're going to get a RN or RN-RT, that is, a registered nurse and registered respiratory therapist - team. These are individuals who have pediatric ICU experience, who have airway skills, who have intubation skills, who have all sorts of resuscitation skills, who will have online communication with the intensivists who they are taking care of. The RN-MD team is us. Texas Children's has the luxury, really, of having a postgraduate physician on every transport. You will find that very few other places in the country. Some places will have an MD for the exceptional transport, but not as a standard part of the transport process.
Pediatric transport is a very new and evolving specialty. There is very little hard data justifying its existence. This is one of the few - and it's really an abstract Dr. Orr has put out of Pittsburgh, and he has some of the best exciting research. But he looked at pediatric transport morbidity and mortality on transport. And what he did was looked at pediatric specialty team transports and non-specialty team transports. He looked at unplanned events over a 12-month period. And he took a mean PRISM score - PRISM score is really an acuity illness score for the pediatric intensive care unit - of 6.7. That's not very sick. These kids are not that sick. They're kind of lower than our average ICU patient at Texas Children's.
And he looked at a distribution of unplanned adverse events in the specialty team versus the non-specialty team. And these were catastrophic or significantly life-threatening events for the non-specialty care providers. And those numbers are really striking, aren't they?

<table>
<thead>
<tr>
<th>Event</th>
<th>Specialty % (N=1,030)</th>
<th>Nonspecialty % (N=55)</th>
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<tbody>
<tr>
<td>Airway</td>
<td>0.4</td>
<td>18</td>
</tr>
<tr>
<td>Hypotension</td>
<td>0.1</td>
<td>10.9</td>
</tr>
<tr>
<td>Arrest</td>
<td>0.3</td>
<td>7.7</td>
</tr>
<tr>
<td>Pneumothorax</td>
<td>0.2</td>
<td>3.6</td>
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Orr RA et al, Transport Medicine, 1999
The morbidity associated with inter-facility transport of a non-specialty team was significantly higher than with a pediatric specialty team. These children were 22 times more likely incidence to have an adverse event. And what he didn't expect was, they were more likely to die. So, further study is warranted, and he's teasing out the statistical variables about what made this separate. But this, to me, was very compelling evidence.
Well, how do I choose mode of transport? A lot of it is distance. How far are we going to go? What is the time frame we need to be there? What kind of carrier and personnel availability do you have? What kind of weather and traffic and cost are you confronted with? Texas is a lot like Australia. We have a large geographic area to cover. Our interstate transports can be 1,200 miles because El Paso is within the state. So we have a lot more to think of than those individuals who are dealing with Chicago and have a small circular radius area to deal with.
One thing that we look at, of course. This is 1993 data from Dr. Brink. Trying to evaluate, helicopters are sort of the sexy component of transport. Everybody loves to see those blades hopping, and jump out of the ambulance and rescue that kid and get him out of your emergency room real fast. They are not cost effective. And the pendulum is swinging the other way. Ten years ago, everybody was using helicopters for everything. Now we're swinging back to ambulances when we can, fixed wing when appropriate. There are certain indications for using helicopters, but they might not always be justifiable. And you can see, when you get out to a 300-mile radius, that fixed wing is actually significantly cheaper. This is in 1993 dollars, and I don't have any more current data.
But we also weigh advantages and disadvantages of different modes. And basically ambulance is universally available, easier to divert - if I'm coming back from Conroe and I need to stop at Northwest Medical Center because my child has clinically deteriorated, it's a lot easier than me finding a helipad to land on, or a runway to utilize. So, we're taking these all into consideration when we're trying to determine how far the youngster goes and what means are we going to do to try and get them there safely. But the most important part of your transport team is not your equipment. It's your personnel. And if your personnel don't have the training behind them, it doesn't matter how expensive their monitors are. You have to have people who know what they're doing behind this.
Well, how can I choose the best team for my patient? Dr. Karen McCloskey, who is one of the forerunners in transport, has written the only pediatric transport medicine text out there. And she tried to evaluate different parameters of, saying, trying to come up with a score. Okay, if my child has these criteria, then I should opt instead of sending them in an ambulance, to get a MD or specialty transport team. She came up with no one variable or particular score that would be helpful. In the last three years the neonatal folks have been able to come up with a few scores that are currently being validated, that may in fact be very helpful for helping you predict whether you need a neonatal transport team.
Likewise, Dr. Rubenstein looked at whether you need an MD or not. And we looked at, again, specific variables about how sick a kid is, trying to score whether they need a physician on transport, whether this child is particularly sick. The key here was the referral physician's opinion. What you say to me on the phone means more than any number that you give me. What is your gut instinct about how that child is doing? Why do you think they're ill? And what do you want us to do to help you? So that's why we want you to tell us what's going on. We want you at the bedside assessing that youngster when you're calling us because that helps us in our decision-making process.
Stressors During Flight

- Acceleration
- Vibration
- Noise
- Thermal
- Hypoxia
- Gas Expansion
- Electromagnetic interface

I'm going to switch gears just a little bit to go to stressors, physiologic stressors of flight. And what makes it different practicing medicine for me there? Well, if any of you have been riding in the back of a noisy ambulance, or even been on a Continental flight to get here, you know that you have your - you are subjected to significant stressors. A couple of them are listed here. Acceleration, vibration, noise. Thermal stress you don't think about, but just sitting next to the window as opposed to the aisle seat, you know how much colder that is. But if I had to pick two factors that were most important in transporting the critically ill child, they'd be hypoxia and gas expansion. And I'm going to subject you to three physics slides in the next few minutes, and hopefully I won't lose you from boredom. But just to illustrate why these two factors are so important for us, if you take a critically ill child and then on top of that, you have to subject them to these additional stressors, you can see why it's an exciting challenge for us to safely transport some of these youngsters in.
Slide 21

Contraindications for Commercial Airline Flights

- CHF
- Myocardial Infarction
- Hypoxic lung disease
- Sickle cell disease
- Anemia
- Air in the CSF space
- Recent middle ear surgery
- Wired mandible
- Recent GI surgery

What does Continental give you as contraindications for flying? And I don't know about you, but I've sat next to many an older gentleman on oxygen starting to complain of chest pain, that I'm getting more nervous every time I fly. But children, adults with congestive heart failure, myocardial infarction, hypoxic lung disease, well, this describes the patients that we transport every day. Air in the CSF space if they've had trauma - a recent middle ear surgery, a wired mandible, or a recent GI surgery. And all these are because of the hypoxic stress and gas expansion phenomena that we face, but these are relative contraindications for commercial airline flights.
Alveolar Oxygenation

$$PAO_2 = (Pb + PH_2O) \times FiO_2 - \frac{PaCO_2(FiO_2 + 1 - FiO_2/R)}{R}$$

- $Pb =$ barometric pressure (760 mmHg at sea)
- $PH_2O =$ vapor pressure of H$_2$O at 37°C
- $R =$ respiratory quotient

But the whole reason that alveolar oxygenation is so important in aircraft flight comes down to barometric pressure. With an increase in altitude, barometric pressure falls. As barometric pressure falls, your alveolar oxygenation will fall concomitantly. So if you have a youngster who is hypoxic at sea level, and then you take them even to a pressurized cabin at about 8,000 feet, that child will be subjected to a hypoxic stress. Most often we can ameliorate that by giving them supplemental oxygen, but barometric pressure is what it all comes down to.
Boyle's law talks about how the volume of a given gas varies inversely with pressure. And you all know this because if you sit, again, on a Southwest Airlines flight that is flying at 35,000 feet, that cabin is pressurized to about 8,000 feet. So there are less oxygen molecules in a given space, and you have to breathe just a little bit faster to achieve the same minute ventilation for yourself. So at sea level, or 760 mmHg, you'll have a given volume of oxygen in ten liters. But you take them up to 8,000 feet, you'll need 13.4 liters to deliver the same amount of oxygen. Those oxygen molecules are spread out further in space.
Henry’s law is really very important for air in a closed space. Specifically, if you remember that nitrogen will expand. This is why youngsters who have a small pneumothorax at sea level, which may not be hemodynamically significant, need to have that pneumothorax decompressed before we take them up in the plane. Otherwise, we will be in a small cabin space trying to deal with expansion of gas at altitude. Because we're transporting in a small space, we always try and do all the procedures before we leave. So that's why we may spend more time in your emergency room than would be helpful.
Dysbarism Decompression really refers to what happens with that gas expansion. So if you have aerodontalgia - any of you who have had dental work and then get on a plane, and know if they leave that small little pocket of air underneath your filling, really - and that gas expands - will have significant pain with that. Chokes, creeping, and paresthesias we are more used to, with diving injuries. Those of you who scuba dive know that you have certain rules about decompression, for example, not flying the next day. And that's all secondary to expanding gas in your spaces.
Four Stages of Hypoxia

- **Indifferent stage** – adapting to the dark
- **Compensatory stage** – increased HR, RR, BP, and CO, sympathetic stress
- **Disturbance stage** – senses impaired with somnolence, HA, restlessness
- **Critical stage** – unconscious, cv collapse, seizures

It's not important that you remember the stages of hypoxia, but remember that it can be an indolent, slow process. This was illustrated only all too well with the crash of Mr. Payne Stewart's plane a couple of years ago, where we think that there was a slow cabin leak. The cabin became depressurized. Everyone slowly became hypoxic and died.
This is why they tell you that when you get on the plane and they say, "When the oxygen mask drops in front of you, put it on yourself first and then on your child second." Because most commercial airlines fly at 35,000 to 40,000 feet. And if you're at 40,000 feet, you don't have much time to get that mask on your face. So you have to be careful about trying to get that mask on your face first.

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<th>Altitude in Feet</th>
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<td>22,000</td>
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<tr>
<td>30,000</td>
<td>5 min.</td>
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<tr>
<td>35,000</td>
<td>1.5 min.</td>
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<tr>
<td>40,000</td>
<td>15 sec.</td>
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<tr>
<td>65,000</td>
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Physiologic Derangements with Air Transport

- ENT – otic barotrauma, sinusitis, dental
- Respiratory – V/Q mismatch, shunt, PVR
- Cardiovascular – venous pooling, CO, acceleration/ deceleration forces
- Hematologic – anemia, Hgb
- Gastroenterologic – trauma, SBO
- Neurologic – ICP, seizure threshold

Well, what kind of physiologic derangements am I faced with, with air transport? In the EENT, problems can include otic barotrauma, sinusitis or dental work, as I mentioned before. Respiratory and neurologic are probably the two big players for me because, of course, those are the two reasons that get you to a pediatric ICU most often. But with the hypoxemia, you can exacerbate VQ mismatch. You can increase your peripheral vascular resistance, and increase your shunt. If you already have a youngster with cardiomyopathy, and you subject him to forces of acceleration and deceleration as you take off and land, that can compromise their cardiac output. So sometimes we'll be pushing volume as we're landing or taking off. If you're already anemic at sea level, and you're subjecting them to further hypoxic stress, you may need to transfuse them before you leave. Sometimes when we have a youngster who is fresh postop, we'll ask them to pack the wound open and leave it open for us for transport because we know that the gas is going to expand within the intestinal space, and if they've already got respiratory compromise, it will be significantly impaired. And thank you all for your kind attention.