Dr. Steven S. Rothenberg, MD is the Chief of Pediatric Surgery at the Rocky Mountain Hospital for Children at Presbyterian/St. Luke's in Denver, CO. He is also a Clinical Professor of Surgery at Columbia University College of Physicians and Surgeons (New York, NY). He is a world leader in the field of endoscopic surgery in infants and children and has pioneered many of the procedures using minimally invasive techniques.

Dr. Rothenberg completed medical school and general surgery residency at the University of Colorado in Denver. He then spent a year in the United Kingdom doing a fellowship in general thoracic surgery prior to returning to the United States, where he completed a 2-year pediatric surgery fellowship at Texas Children’s Hospital in Houston. He returned to Colorado in 1992, where he has been in practice for more than 20 years.

Dr. Rothenberg was one of the founding members of the International Pediatric Surgical Group (IPEG) and is a Past-President. He was also the Chair of the Pediatric Committee and on the Board of Directors for SAGES (The Society of American Gastrointestinal Endoscopic Surgeons). He has authored over 180 publications on minimally invasive surgery in children and has given over 300 lectures on the subject nationally and internationally. He is also on the editorial boards for the Journal of Laparoendoscopic Surgery and Advanced Surgical Techniques, the Journal of Pediatric Surgery, and Pediatric Surgery International.

Dr. Rothenberg has been married to his wife Susan for over 30 years and has three children, Jessica, Catherine, and Zachary. He is an avid outdoorsman and spends most of his free time in the mountains of Colorado skiing, hiking, biking, and fishing.

Dr. Rothenberg, let me begin by thanking you for the opportunity to interview you on the evolution of minimally invasive thoracic surgery in infants and children. You are considered by most of the pediatric surgery world as the pioneer in this area. What originally prompted you to undertake a fellowship in thoracic surgery?

It was an interesting combination of circumstances. I applied for the thoracic surgery fellowship during my chief year of general surgery. Early in my chief year, I had a patient at the county hospital who had metastatic thoracic rhabdomyosarcoma, and my thoracic attending surgeon from the university hospital came over to help me out.

During the operation, he inquired about my plans after finishing my chief year. I explained that I was applying to pediatric surgery, but that I would appreciate more thoracic experience.

He then told me that he was leaving the next day for England as a visiting professor and that one of the Senior Registrars from the cardiothoracic center in Liverpool had been in his lab the previous year. He offered to make some inquiries about any potential positions while he was there. Surprisingly, he came back a week later and said, “You have a job.” The Senior Registrar at Broadgreen Hospital in Liverpool was going to come to Colorado for a year, and I was going to go be their Senior Registrar and do thoracic surgery for a year, which was perfect because I had a year break before starting pediatric surgery.

At that time, did you envision, or anticipate, that your career would bring you this far down the thoracic surgery route?

I always liked thoracic surgery, and I thought it would be an interesting specialty. When we look back at the
So after the year of thoracic surgery, you came back and did pediatric surgery. Was there a point in time during your pediatric surgery fellowship that you decided to embark upon thoracic surgery as a primary focus of your practice, and how did you begin the minimally invasive changes that you are so well known for?

Like everyone else in that time, I did a few cases during fellowship. And they were all open. When I was in fellowship, from 1990 to 1992, we did not do anything minimally invasively. This was the time right after laparoscopy started.

Then, I came back to Denver and became affiliated with a hospital in town called National Jewish Health, which happens to be one of the top hospitals in the country for allergy, immunology, and respiratory diseases. They get kids from all over the country in referral for evaluation of complex respiratory issues.

At that time it became apparent that there might be a significant number of pulmonary cases, because I knew they were doing some lung biopsies in an effort to find diagnoses in these children. I thought, "I know I could do these thoracoscopically." Although I knew we could do it, I was not quite sure how to mechanize it. Again, I was lucky that I knew a surgeon by the name of John Simon. John worked at one of the private hospitals in town, where I had trained at as a resident, and he did general and thoracic surgery.

I had heard that he was working on adult patients who had significant interstitial lung disease. He was performing lung biopsies and lung reduction surgeries in these patients.

I called him up, and he invited me to come and observe him doing a few lung biopsies and a couple of these lung reduction surgeries. The basic premise of the operation was to go and staple off these giant blebs. This was just after the endoscopic stapler had become available. It was kind of an "Aha" moment, and I thought, "Well, I can do this at least in larger kids."

The next big step occurred when I went and spoke to the head of pediatric pulmonary at National Jewish, Leland Fan. I told him, "I can do your lung biopsies thoracoscopically," and he said, "How?"

I needed to show him, so I actually set up an animal lab, I brought him into the lab, and I did a thoracoscopic lung biopsy on a pig. He was one of the first people to adopt flexible endoscopy, so he really got it!

About 2 weeks later, he called me about a patient: a boy about 10 years old with a cavitary lesion in his lung. They had worked him up, and nobody could make the diagnosis.

I saw the patient, and I explained to the family what I wanted to do. I took him to surgery, and you could see the lesion on the surface of the lung. I wedged it out with a couple shots of the Endo GIA, and it turned out to be Legionella. It was a wild case. That case sort of set it off; they started referring over all the patients with interstitial lung disease and things like that. So ultimately, it really started with the lung biopsies.

Simultaneously, laparoscopy took off, correct?

You are right, to put it lightly, laparoscopy took off. Again, I was lucky that I was in a practice where we did a lot of gastric reflux surgery, and my skills really expanded from doing antireflux operations.

What about other early thoracoscopic procedures?

The other unique situation that I was in was that we did not have a cardiac surgeon when I initially started at our hospital. Subsequently, the cardiac surgeons from the university were coming over to do the patent ductus arteriosus (PDA) procedures. When I arrived in Denver, I told the neonatologist that I had done a thoracic fellowship and I would be available, and I wanted to do them.

I had been thinking about doing a PDA thoracoscopically, and then I read a report by a surgeon in France, Laborde, who had done a thoracoscopic PDA. I thought, "I can do that." So I reached out to our cardiologists and told them, "You do not need to refer these to the cardiac surgeons. I can do these thoracoscopically."

This was the procedure that made me realize how good the visualization of the posterior mediastinum was thoracoscopically, which led me to attempt other procedures for lesions in the posterior mediastinum. I think I did my first esophageal duplication about 2 years after I had been in practice. That was the early progression.

Then came lung surgery. I started to think that we could probably do a lobectomy thoracoscopically, but we were limited by the instruments and the equipment to do it.

How did you overcome the lack of instrumentation?

The first attempts were like a mini-thoracotomy. I did a little muscle-sparing incision. The incision was probably
about 5 or 6 cm large, sparing the serratus and the latissimus. I had this open incision, and then I put a couple of ports in with the scope and learned to try to operate that way. A lot of time I spent looking through that little incision trying to see what I was doing, which was not great.

At that point, vessel and bronchial control was all via clip applicers and ties?

Yes, pretty much. Vessel sealing had really not come along yet. We did have staplers, and we were trying to use those. These were very tedious procedures, very time-consuming—really hard and really stressful. But I was learning and developing the approach. I learned a couple different things, both with the PDAs and with the lung resections.

When I had done those surgeries open, I always stood at the patient’s back. One of the things I figured out pretty early is that it is actually much better to stand at the patient’s front. We were progressing, and when we finally got a 5-mm clip applicer and some of the other early devices, I was slowly getting rid of the mini-thoracotomy.

Then I was introduced to vessel sealing, and things really changed. Initially there was the Harmonic scalpel, which was pretty amazing in the way it could seal and divide tissues.

But the real breakthrough for me was when I was introduced to the LigaSure, which was vessel-sealing technology that would work on bigger vessels and would not divide them. That became a way to approach pulmonary vessels; it allowed us to save the time to tie individually or clip each vessel.

The thing I always worried about with clips is that they would come off, or that you would knock them off. I never did like that technique. I embraced using vessel sealing early, and it really enabled me to do more complex surgeries, things like complete lobectomies, especially in the smaller kids, in a more efficient fashion. You could now make a couple of seals and divide just as though you had tied it off. It just seemed a much safer and better way to go.

The Harmonic seals and cut at the same time. Dividing a pulmonary vessel without having the ability to evaluate the seal first would be quite unsettling.

Right. So that did not really work. I think I tried it initially early on. But I was not happy with that. It was not until I got introduced to the LigaSure that my view really changed. One of the company’s [Covidien’s] initial devices was called the LS1000. It was as good as any disposable instrument that had been up to that point; it had a fine tip. It looked like a big Maryland, but you could dissect with it.

It allowed me to dissect and seal, which was much more efficient. It worked well in smaller kids, and most of the cases for lobectomies were kids with congenital cystic lung disease. The problem was, it was just way too big, especially in neonates.

Regardless, it did allow me to develop that technique of seal, seal, and divide between them, which I felt was very safe. The concept was that you could make your seals and then cut the vessel partway. If the vessels started to bleed, you had the opportunity to do something before the vessels retracted and you lost control. To me, that was what we really needed, because everybody was nervous about having the chest closed and not being able to just put your finger on a bleeder to stop it.

How long did you continue doing lung surgery, esophageal duplication, bronchogenic cysts, and so forth, before you thought about doing an atresia or a TEF?

Well, I think I did my first lobectomy in 1994. And that was one of the kind of mini-VATS [video-assisted thoracoscopic lobectomy] incision cases. So it was probably a couple more years before I completely got rid of that. But like I said, it was the PDA that really made me think that we could do an esophageal atresia. The PDA got me used to the posterior mediastinum and standing in front. Once I got to the front of the patients and I started turning them a little bit prone to get the lung out of the way, I realized the approach was exactly the same as for a tracheoesophageal fistula (TEF). However, for me, the issue with the TEF was really going to be the ability to sew in that small space.

I actually thought we were going to need a robot to do it because it was such a small space. I worked a little bit with the robot companies, but the robot was just too big to go there, and it could not really help us.

The breakthrough came in 1999, before the IPEG meeting in Berlin. I had gotten an e-mail from Professor Waldschmidt, who was hosting the meeting that year. He had written Tom Lobe and me and said, “I have this kid with pure esophageal atresia. He is 2 months old now. We have been putting bougies down every other day to stretch the esophagus out.” He sent a picture that showed the two ends of the esophagus, almost touching each other. As you know, in 1999 we were still doing live surgery events as part of IPEG. He asked, “Do you guys think you could do this thoracoscopically while you are here for IPEG?”

Tom and I talked about it, and we thought yes, we probably can. Neither of us had done it before, but we agreed would give it a try.

At the time of the operation, we spent about 2 hours trying to get single-lung ventilation because we thought that would be critical. We now know that it really isn’t that important, but at time we tried all sorts of stuff. We finally were able to occlude his right main stem with the Fogarty. The visualization was good, and the mobilization wasn’t that difficult. We eventually got the two ends together. It was not the prettiest thing in the world, but we got it done. It took about 3 hours once we started. The baby had a little postoperative leak, which closed spontaneously, but he actually healed.
That was the first time that we had accomplished it, and it was really apparent that the focus that I had placed building up my skills for suturing was critical for that operation. After that, I was just waiting for the right TEF to come. I wanted a close-to-term, bigger, healthy baby. I also had been thinking, “I bet I could just clip the fistula, which would be quicker than suturing it, allowing me to close the fistula quickly and get rid of that air leak, and maybe that will help anesthesia.”

And so I waited, and waited, and then it happened. I had a 2.8-kg baby come in, totally healthy, with a TEF. I told the parents what I had done, and I felt I could do this thoracoscopically. They agreed to allow me to try to do it that way.

And we did it. It took about 2 hours. I clipped the fistula and then sewed the anastomosis. Again, it was not real pretty, but it worked. I was so relieved when the study on Day 5 showed no leak, and he was able to eat.

Interestingly enough, it happened 4 days before the 2000 IPEG meeting. I was President and Program Chair that year. It was held in Atlanta, and it was the first year that IPEG and SAGES met together.

I ran home with the video and edited it, and then left for the IPEG meeting. A paper canceled, which allowed me the opportunity to put the video in as a replacement. I inserted the video into the program without telling anybody—showed it at the meeting. I think there were about 250 people in the meeting, and you could just see everybody’s jaw drop when they saw the video. That was the start of it.

It would be great to hear about some of the advances that you have seen. You talked about energy sealing and other sealing devices. What do you see now as the big next thing that is going to allow people to continue to expand on minimally invasive thorascoscopic surgery?

For pediatric surgeons, there are several issues. One is technical skills needed for minimally invasive surgery. I think we are seeing great improvements in the trainees in this regard. We are training surgeons so they have much more dexterity, and they are able to do fine-manipulation suturing and things like that.

The biggest problem that with continues infants and small children is that the instrumentation that is available to us has all been too big. It is 12-mm staplers and 5-mm sealing devices that are just too big and do not work very well in those spaces, and do not dissect well for delicate tissues. Fortunately, one of the things that has happened over the last couple of years is that now we are actually making smaller instrumentation. We now have a 3-mm sealer device that looks like a Maryland, is a much finer dissecting instrument, and is much easier for most surgeons to use because they are not struggling with the size of the instrument in a small space.

And the 5-mm stapler that is now available makes it much easier to take the bronchus, as well as the pulmonary vessels. A case in point: recently, I helped the pediatric surgery fellow at Columbia in New York do a right lower lobectomy in a 3-month-old. The baby had an intralobar sequestration with a huge systemic vessel coming off the aorta.

During the operation, we tried to put the biggest clips we had on it, but they did not go across it. We actually pulled the clips off and used the 5-mm stapler on it, which worked great. Previously, this would have required intracorporeal knots. He did the entire operation himself, dissecting out the pulmonary artery to the right lower lobe. He used the 5-mm stapler to control the artery at the trunk. He used one application of the stapler to take the pulmonary artery as opposed to doing what I would have done previously, which is just get the segmental vessels and seal them and divide them.

Similarly, he took the bronchus and the pulmonary vein using the same 5-mm stapler. It took him just over an hour to do the operation. This is the kind of technology that is really going to facilitate other people’s ability to do these kinds of operations. Don’t take me wrong, you still have to have the technical skills to do the dissection. But I think that as this type of instrumentation continues to improve we will see significant advances; just as we do not think twice about taking a pulmonary artery in a teenager with an Endo GIA, I think we will be able to do it in small babies, as well.

So miniaturization of the sealing and stapling technology is making it easier. Another important advancement is high-definition cameras; the visualization is better, which makes the operations safer and quicker. I think for lobectomies that you do not need to have single-lung ventilation, but it is nice to have.

In terms of esophageal atresia, we still need something that is going to make it easier for people to do an anastomosis in the chest. There are more and more surgeons who can do it, but that is still a technical hurdle for a lot of people.

What would you say to somebody newly approaching thorascoscopic surgery?

You start with basic things, and you need to have a team and a concept and an idea of how you are going to approach it. You do simple things like lung biopsies and nonvascular masses, like esophageal duplications. Posterior mediastinal masses usually are good. You do anterior mediastinal biopsies, just to get familiar.

I think the biggest issue, though, for the more complex surgeries, like lobectomies, is just awareness of the anatomy. And I think that is probably something that my fellowship helped me with more than anything else. I know the anatomy of the chest, and so not having my hands in there is not as much of a problem. That year fellowship has made it easier for me to visualize things three-dimensionally and understand the spatial relationships. That is what you really lose when you do a thorascoscopic procedure; you cannot feel things. You have to really understand where things are in terms of layers.

It is a stepwise progression, and I think it is really a matter of studying the anatomy so that you are really comfortable
with it and learning the different approaches—how you can get around things and get access to things without having your hands in there.

Do you have any parting thoughts that you think are important in terms of the advances in the development of thoracoscopic minimally invasive surgery in the pediatric population?

We are probably doing more hybrid procedures. For example, for some of the esophageal work we do now, we have a gastroscope in the stomach and an esophagoscopy to help identify things and do it. I think there will be more of these types of procedures, where perhaps we will do more with a flexible scope and less through the thoracoscopic ports. I think that is something that is coming down the line.

We now know all the procedures can be done. It is a matter of making it easier for more surgeons and having them feel comfortable with the techniques.

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