More than Measures and Mechanics

The Art of Breathing

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The most important things are performed via pipes.
First proof:
the tools for procreation, the writing pen and the gun;
what else is man but a confusing bundle of pipes!

*Georg Christoph Lichtenberg**

For more than 100 years, we have been looking down the airways, and like the astronomers of old looking up at the sky, we are still struck with awe by the complexity of the human anatomy. The more instruments we use to explore its structure and function, the more we realize how our judgment is frequently based on wrong assumptions. In many respects we are not so far from Andreas Vesalius who from his observations considered the windpipe to be part of the circulatory system and with reference to its internal surface called it 'arteria aspera' (rough artery or *τραχὺς* [trachys] rough in Greek, hence the name trachea) [1]. When he insufflated air into the trachea of apneic animals with an open chest by vivisection, the heart, which had arrested, started beating again. And yet, the year 1543, in which he published the first anatomical observations in humans in *De humani corporis fabrica* (The structure of the human body) and Copernicus published *De revolutionibus orbium coelestium* (On

the revolution of the celestial spheres) [2], is considered the end of the dark Middle Ages and the beginning of modern times.

The basic reason for inventing bronchoscopy in 1897 by Gustav Killian was an intervention to remove foreign bodies [3]. Already back then it was observed that the wall was rather fragile, and frequently after removal damage of the wall resulting in stenosis persisted. Thus, methods for dilatation and stenting were developed [4]. Meantime, we are treating a large variety of stenoses needing different techniques for intervention. Ironically, apparently the outcome of our interventions, interfering with the anatomy and normal function, provides more insight than the observation of healthy airways. Although the paper of Rooney et al. [5] in this issue of *Respiration* on three-dimensional CT reconstruction for balloon dilatation raised more questions than answers for the reviewers, we considered it still worth being published as it creates an opportunity to raise some topics in the treatment of central airway stenosis that deserve further discussion and research: (1) the anatomy, (2) the function, (3) the intervention, (4) the materials and (5) the outcome.

By experience, the wall of the airways is a complex structure of flexible and rigid components that are essential for its function and are the most important issue in treatment [6]. Their integrity is a crucial feature, and pre-interventional analysis is essential for the decision on the technique to choose. Current radiological methods are insufficient to analyze these structures. In a prospective preoperative study, Caretti et al. [7] demonstrated that

* Georg Christoph Lichtenberg (1742–1799), philosopher, scientist and aphoristic writer in the era of enlightenment, *Scripts and Letters*, first volume, *Sudelbücher* (sketch books). Frankfurt/Main, Zweitausendeins Publishers, 1994, E 35, p 349.

CT with multiplanar reconstruction was inferior to flexible and rigid bronchoscopy in the assessment of the extent of tracheal stenosis. CT evaluation can result in underestimation up to 1 cm. Increased sensitivity by high-speed multislice spiral CT is considered superior in the analysis of the integrity of the bronchial wall [8]. However, in a recent paper, Miyazawa et al. [9] described that in several cases, only by combining ultrathin endoscopes and endobronchial ultrasound, reliable prediction of the site and extent of stenoses could be assessed. Whether a new technique applying laser measurement might be more reliable has to be investigated [10].

Integrity of the structures is essential for their function. This implies breathing and clearance of secretions. Whereas breathing is reestablished by most devices, mucus clearance is a problem in all devices. The mechanism of air flow in the airways is still not clearly understood. In contrast to blood vessels, basically there is no laminar flow inside the airways. In a recent experimental study, air flow was determined as chaotic and obeying fractal laws [11]. However, observing the course of secretions along the airway wall, a constant feature is its spiral transport against gravity [12]. This applies to the peripheral and to the central airways. The first observation was the mucus spirals in asthmatics described by Curshmann (quoted in [6]). An essential, up to now obviously underestimated factor is the arrangement of the cartilages. From industrial construction it is known that drainage is most efficient by adding spiral protrusions to the internal surface of tubes [13]. In addition, the interface of the mucosal lining with its anti-sticking and antibacterial features is an important component that is still not copied by current stents.

The type of intervention mainly depends on the underlying pathology. This was the main point of discussion by the reviewers of the paper by Rooney et al. Although the papers on interventional procedures are legion, and there are textbooks and several editorials on the optimal management of central airway stenosis [14–16], prospective studies directly comparing the different techniques are lacking. In my opinion, this is due mainly to three reasons. First there is no common terminology concerning the different entities. This may be an explanation why the positive results of treatment by balloon dilatation described in Rooney's paper are so different compared to the experience described by most specialists in this field. Second, probably in the minority of cases, the decision on the optimal therapeutic procedure is made by an interdisciplinary panel of specialists. Thus patient selection criteria for intervention can be very different, and the

severity and risk may differ widely [17]. Lastly, even prospective studies comparing techniques can be biased by the preferences and skills of the individual bronchoscopist in the different methods for intervention [18].

There is no material that can compare to the elasticity and yet unbelievable endurance of the body tissues. Some materials are mechanically very resistant, but comparatively stiff like silicone or PTFE (Teflon). If plastics are too thin, they fracture as can be observed in the dorsal wall of dynamic stents. Even metals can be corroded in the aggressive environment and if they are too rigid they perforate the airways. Nitinol, an alloy of nickel and titanium most closely resembling the mechanics of elastic tissue, can fracture under fatigue. This is why currently a lot of efforts are made to replace damaged airways by biological tissues. Interestingly, even a completely different organ like the aorta can assume an airway structure by developing mucosa and even cartilages [19].

With regard to outcome, conventional lung function tests frequently do not reflect the often dramatic improvement in the patient's condition. In a recent study, we were able to show that analyzing work of breathing and improvement in the 6-min walking test may be more accurate than objective measures [20], which seems in analogy of preoperative risk assessment by the ability to climb stairs. In a recent paper, Miyazawa et al. [9] demonstrated that in some instances after stenting of the stenosis, the flow-limiting segment (choking point) can be shifted more peripherally, and additional stenting is warranted. The choke point can be camouflaged by superimposed lesions and it can only be detected by a complex diagnostic procedure including endobronchial ultrasonography, ultrathin bronchoscopy and three-dimensional CT scan. Whether future techniques such as the DeepBreeze® VRI2000 facilitate improved pre-interventional assessment has to be seen (<http://www.deepbreeze.com/content.asp?id=64>).

These examples might demonstrate that despite years of experience in treating central airway stenosis more questions are open than answered. Airway obstruction and stenting is far more complex than initially thought [21], and new efforts are warranted to clarify these issues. Man is much more than a confusing bundle of pipes ...

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