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Pulse oximeters: personal recollections of the past and hopes for the future

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What I regret about the pulse oximeter

Could I have worked like Dr. New?

It was probably sometime in 1976 when I first came across a Minolta model of the pulse oximeter. I immediately realized its merit and potential, as well as its drawbacks. I had young Dr. Suzukawa with me then, had him work on it and collect data, and had him write a paper [1].

It was probably a year or two before Dr. New saw the same instrument. While practicing anesthesia in the university environment, Dr. New, as soon as he saw the instrument, took the opportunity, improved the instrument, and subsequently established the Nelcor Company. While I realized its merits and its potential, I had no intention of pursuing it myself as Dr. New did, missing a good chance of improving and having business on the pulse oximeter myself.

We somehow missed publishing an important study in English

Dr. Suzukawa's paper was published only in Japanese. It was translated into English of high quality, with the help of Mr. Nakamura, a professional science writer. Somehow, however, this English version was never submitted to any English-language journal. This paper, of which only the abstract was in English, has been quoted many times since then. Dr. Suzukawa himself was quite young at that time, and it was entirely my responsibility to decide whether to submit what, where, and when. I greatly regret that I failed to make just a little more effort to submit it somewhere.

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I also failed to find Dr. Aoyagi

Dr. Aoyagi, who discovered the principle of pulse oximetry, patented it, and assembled a trial version of the instrument in the early 1970s, became known to us only with the help of Professor John W. Severinghaus of the University of California, San Francisco, in the mid 1980s, many years after Dr. Aoyagi's original work. While studying pulse oximeters and the history of blood gas measurement, Professor Severinghaus became interested in the question of who really invented the pulse oximeter. After discovering that the pulse oximeter was invented somewhere in Japan, he consulted Dr. Honda, then the Professor of Physiology at Chiba University, with whom he had been cooperating for some time. Dr. Honda, with some effort, traced Dr. Aoyagi and gave this information to Professor Severinghaus. Professor Severinghaus then wrote an article in the *Journal of Clinical Monitoring*, in which he introduced Dr. Aoyagi as the discoverer of the principle of pulse oximetry and the inventor of the instrument [2].

He subsequently organized a book, and this information became well known to those in this field. The world soon came to realize how the pulse oximeter came about [3]. I regret that I did not contribute anything to this important historical tracing. I also regret that when Dr. Aoyagi presented his work for the first time in public in 1974 in Osaka, I attended the meeting but missed his presentation. It was a big meeting where many sessions were going simultaneously, and I did not attend this particular session. The abstract had been sitting in my bookshelf, but I found this many years later.

What I am proud of about the pulse oximeter

I could at least realize its merit at the very first instant

Although I have various regrets in my personal history of pulse oximeters, I have a few matters to be proud of about this instrument. I could at least realize its merit at the very instant when I first came across it and became quite enthusiastic.

The Minolta pulse oximeter was supplied to us for the purpose of clinical trials, and it was the one that Dr. Suzukawa studied and wrote an article about. When I successfully applied for the fund from the Ministry of Education and Culture of the Japanese Government in the following year, I bought this instrument from the company. From what I was told, the Minolta Company, while they had successfully patented the pulse oximeter outside Japan (the domestic patent was already held by Nihon-Kohden, to which Dr. Aoyagi belongs), sold only about 100 units before major revisions were made by Nelcor and Biox using a combination of digital technology and optical diodes. I am also glad that I did have the sense to write about this Minolta instrument in one of my books on the early history of pulse oximeters [4].

So I may take pride quietly in the fact that I was smart enough to be aware of the potential of the instrument.

Pleasant memory of a joke

It must have been some time in the mid-1980s. The chairman of the anesthesiology department in a big hospital made a complaint to me. He said that the vice-chairman of his department had arranged to buy and set up many pulse oximeter units so that every operating room in his hospital would be equipped with a unit while the chairman was on sick leave. He then insisted that they should not rely on such devices to determine the oxygen level of patients. I immediately countered the chairman's complaint by saying, "By taking sick-leave, you have done a great service to the department and to your patients. With the help of pulse oximeters, your patients will be much safer and do much better under anesthesia. Also your residents will learn more quickly of oxygen dynamics during anesthesia." He might have taken my statement as a joke, but I was more serious than I sounded.

Use of a pulse oximeter on the Emperor

The late Showa Emperor had his laparotomy done in September 1987. The hospital was staffed and equipped quite poorly at that time. We had to transfer a lot of instruments as well as personnel and information from the University Hospital. We moved one of the pulse oximeters of which, at that time, we had only four units for the entire operating theater, consisting of some 14 operating rooms.

After the surgery, journalists were eager to know everything we did to this patient. In one of the information exchange sessions, I mentioned the pulse oximeter with some explanation, which they immediately captured and asked me to write an article about for the newspaper, which I did. It was probably the first time the pulse oximeter became known to the general public beyond the medical environment. I was quite aware of the possibility at least that such an article would help the practicing anesthesiologists of many hospitals to ask the hospital administration to buy and set up pulse oximeters in their operating rooms.

Future of the pulse oximeter

Pulse oximeters beyond the medical environment

Finally, may I express my view of what the future of the pulse oximeter should be, especially how it should be used beyond the medical environment. The pulse oximeter is such a simple instrument, with easy use and no moving parts necessary, that it may be suitable for use by the general public. It can be mass-produced much less expensively than it is now. In essence, I believe the pulse oximeter may be treated as one of the "health instruments" for the general public, similar to small blood-pressure machines.

There are many reasons for such a claim. Society, especially that in Japan, is growing old quite rapidly. We know, however, relatively little of the oxygen dynamics of old people. There are some data for people resting, but data are quite scanty for daily activities and stresses. Some data suggest that under minor stress Sp_{O_2} values in old people decrease much more markedly than those in young or middle-aged people.

Problems of commercial flight: drastic falls in Sp_{O_2}? [5] (Fig. 1)

During commercial flights, because of the reduced cabin pressure, Sp_{O_2} values are a few percent lower than normal. This difference is probably insignificant as long as the passengers are healthy and remain awake. Once they fall asleep, however, things become entirely different. Among the passengers, there are many who suffer from sleep apnea syndrome, especially on long-range flight when they sleep with the help of quite generously supplied liquor. During apnea for 30 s, Sp_{O_2} values may fall by a few percent below atmospheric pressure. In the cabin, however, they may fall as much as 10 to 15 percent, because the starting Sp_{O_2} values are already lower and, moreover, they are on the steep portion of the oxygen dissociation curve. This is a dangerous situation, yet nobody is aware of it.

Many accidents have been reported during commercial flights; there is no question that venous and pulmonary emboli are important. The above-mentioned mechanism, however, has never really been studied or

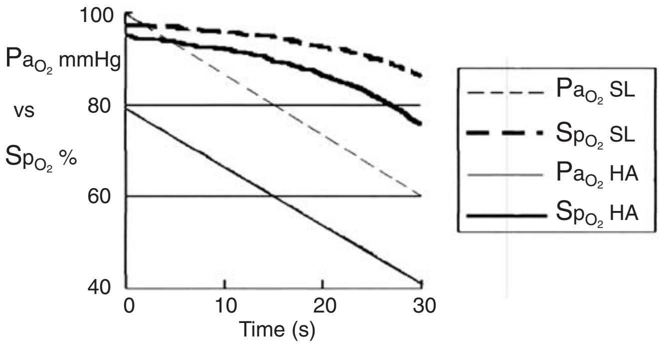

Fig. 1. Decreases in Pa_{O_2} and Sp_{O_2} theoretically calculated during apnea of 30s starting from functional residual capacity (*FRC*) at sea level (*SL*) and at high altitude (*HA*) are shown. The pressure at high altitude is assumed to be 614 mmHg, equivalent to 1700 m of altitude, roughly equal to the cabin pressure of commercial flights. FRC and oxygen consumption are assumed to be normal. Note that the decrease in Sp_{O_2} at high altitude is much more marked than that at sea level

even questioned. Although only theoretical at this moment, there are good reasons to believe that hypoxic events must be playing a significant role in accidents occurring during commercial flights.

The use of the pulse oximeter will disclose such problems. There must be many more situations where the fall in Sp_{O_2} values is considerable without being noticed currently. The opportunities are wide open for the pulse oximeter to be applied and studied.

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