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CLINICAL REPORT

Toe gangrene in an infant subsequent to application of adult-type pulse oximeter probe for 10 min

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Abstract We present a case of ischemic changes after application of an adult pulse oximeter probe in an infant for a short period of only 10 min. To understand the physiology behind this mishap, we studied pressure exerted by the adult pulse oximeter probe on simulated fingers (fluid-filled pouches), which were filled under gravity through the three-way stopcock. A catheter was placed inside the pouch to continuously measure the pressure. The experiment was performed on different sizes of the finger-shaped pouches and by varying the positioning of the pouches in the pulse oximeter. It was observed that pressure exerted by the pulse oximeter was directly proportional to the extent to which it was stretched after placement on the fluid-filled pouches of different sizes. In the fully extended position, the pressure exerted was higher (up to 30 mmHg) than in the fully collapsed position (4 mmHg). Higher pressures were caused by greater stretch of the probe. This could occur due to larger fingers and closer placement of fingers to the hinge of the probe.

Keywords Gangrene · Pulse oximeter · Infant

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Introduction

Toe gangrene subsequent to application of a pulse oximeter probe is a rare occurrence, with only two cases previously described [1, 2]. We report an infant who developed ischemic changes after application of an adult pulse oximeter probe to the toe for a short period of only 10 min. We also conducted an experiment to establish the physiology behind this occurrence by using simulated fingers.

Case report

A 1.5-month-old boy with Peter's anomaly and weighing 2.7 kg presented with corneal opacity and was scheduled to be examined under general anesthesia. In the operating room, an adult-type pulse oximeter (Datex Ohmeda S/5 Avance) was applied over the first and second toes of the left foot because the wrap of the pediatric probe was damaged and unavailable at that time and the procedure was short. Anesthesia was induced and maintained with sevoflurane, oxygen, and nitrous oxide. The total duration was 10 min. The child was discharged in an apparently good condition. However, the next day, the mother noticed blackish discoloration of first and second toes of the left foot, the site where the probe had been attached (Fig. 1).

The child was referred to the pediatrics department where various causes for the occurrence of ischemic changes, such as pneumococcal sepsis, vasculitis, and thermal injury due to a warming blower, were ruled out. Doppler study demonstrated unobstructed flow and patent veins and arteries. A final diagnosis of dry gangrene was made. Conservative management with adequate hydration was advised. The toes subsequently healed over the following week, and the child was discharged after 7 days.

Fig. 1 Gangrene in the first and second toes where the adult-type pulse oximeter was applied

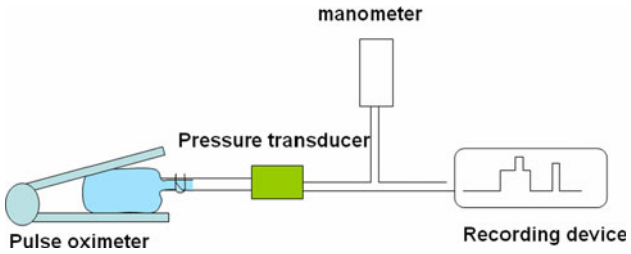

Fig. 2 Setup for recording pulse oximeter pressure on fluid-filled pouches simulating fingers by connecting to a manometer

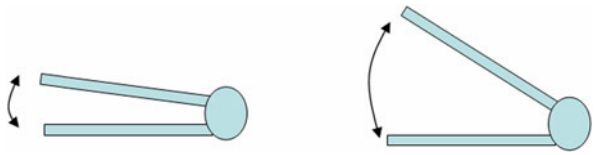

Fig. 3 Fully extended probe, pressure is up to 30 mmHg; fully collapsed probe, pressure is 4 mmHg

Discussion

Peters anomaly is a rare form of anterior segment dysgenesis of eye with an unknown incidence. Vulnerability to skin injury is unknown and not described previously. Few case reports have reported toe gangrene subsequent to application of a pulse oximeter probe [1–8]. In normotensive individuals, the skin is able to autoregulate blood flow under 10–30 mmHg of externally applied pressure. However, autoregulation above this pressure range results in skin blood flow values of only 31–35% of normal [9]. Thereafter, with increasing externally applied pressure >60 mmHg, blood flow declines rapidly, resulting in blood flow values of <9% of normal [9]. Either high pressures for short periods or lower pressures for longer periods may cause tissue ischemia [10].

None of the described cases have quantified the pressure exerted by the adult pulse oximeter probe on the peripheral circulation. We measured the pressure exerted by the pulse oximeter probe on finger-shaped fluid-filled rubber pouches in the department of physiology. The finger pouches were made by cutting the finger end of latex surgical glove no. 6. The pouches were filled with tap water and the ends tied. The experiment was done on two finger pouches. One was the little finger, with the following measurements: circumference 4 cm, radius 0.63 cm on inflation and length 1.5, 2, and 3 cm. Second was the index finger, with circumference 5 cm, radius: 0.79 cm on inflation, and length 2 and 3 cm. A catheter was placed inside the pouch to continuously measure the pressure through a three-way stopcock. Before application of the probe over the pouch, the pressure transducer was calibrated. The pouches were filled under gravity through the three-way stopcock (Fig. 2). The length of tubing was <1 foot. Before probe application, the pressure in the pouches was just above 0 mmHg. The instrument was calibrated against a mercury manometer to create known deflection for 10 and 20 mmHg of pressure. The pulse oximeter was then applied to the pouch and the deflection was noted. The process was repeated to ensure precision and accuracy (Fig. 2).

The pressure exerted was tested on the pouches and by varying pouch position in the pulse oximeter. It was observed that pressure exerted by the pulse oximeter was directly proportional to the extent to which it was stretched after placement on the pouch. It was found that the amount of stretch of the probe depended on the placement site on the pouch as well as pouch size. In fully extended position, the pressure exerted was higher (up to 30 mmHg) than in the fully collapsed position (4 mmHg) (Fig. 3).

Our experiment may not reflect the exact physiology, as a "real" finger would differ from our fluid-filled pouches. Nevertheless, it conveys that the closer the finger is placed to the hinge of the probe and the larger the finger size, the greater the probe is stretched and the higher the exerted pressure. The adult pulse oximeter probe was placed over two toes (≈length 1.5 cm, radius 2 cm) of our infant patient, completely covering the toes, to attain a better signal. The extended probe created sufficiently high pressure to cause a decline in skin blood flow. Because the probe was applied for a short period, the outcome was favorable.

Probe integrity was intact as checked by the company engineer. Temperature in the probe rose to 32.4°C within 10 min. However, the relative pressure-induced reduction of circulation under the probe can reduce the capacity for transport of heat away from the sensor and thereby indirectly contribute to thermal damage by the probe [5].

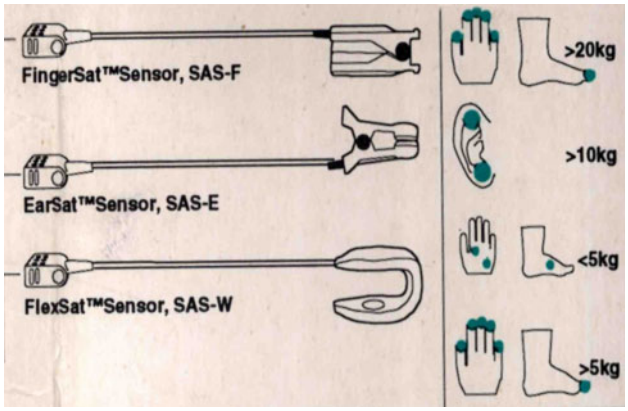

Fig. 4 Recommended probe types for different weights

Even though the probe on our patient was intact, because of decreased circulation beneath it, it also probably caused increased temperature. Even in adult patients, pressure and ischemic injuries are increased by prolonged or tight probe application and compromised perfusion of the extremity. Patients with large fingers should not have a circumferential probe placed on the finger. If the pulse oximeter reading appears to be weak, the site should be checked. Frequent examination and moving the probe to different sites will reduce the likelihood of injury [11].

Though each of the two factors, increased pressure and temperature, would probably not be detrimental alone, in combination, they caused ischemia and pregangrenous changes. The outcome was less serious in our patient because of the short period of application. The lesson learnt was that the adult-type pulse oximeter should not be used in infants, even for short procedures, and that one should always adhere to recommended probe sizes (Fig. 4; adapted from Datex Ohmeda user manual). We also recommend that each manufacturer should state on their instruction for use of adult reusable probes that use on an infant is either contraindicated or must be done with caution.

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