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The Predictive Value of Pulse Oximeters for Pulse Improvement after Angiography in Infants and Children

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Abstract

Background: Information from pulse oximeter waves confirms the presence of a pulse and helps obtain waves from tissue when the supplying artery is not readily accessible.
Objectives: This study determined the predictive value of pulse oximeters for detecting improved arterial pulses after angiography.
Patients and Methods: This cross-sectional, multi-center study included 467 4-day-old to 12-year-old patients and was conducted from January 2012 to January 2016. Angiographies were performed on 12-year-old or younger children for various medical reasons using venous, arterial, or both types of paths. The posterior malleolar or dorsalis pedis were palpated in punctured lower extremities. In the absence of a pulse, pulse oximetry was performed to identify pulse curves at 1 hour, 6 hours, and 12 hours after each angiography.
Results: Pulse oximetry displayed the pulses of 319 patients immediately following each angiography. Of these, 262 patients had palpable pulses at 6 hours after angiography ($P < 0.0001$), while 57 patients had no palpable pulse. Of these 57 patients, 15 had no palpable pulse at 12 hours after angiography ($P < 0.0001$). The odds of pulse improvement in children 6 hours after catheter angiography were 76% for the arterial path, 90% for the venous path, and 83.2% for both paths. At 12 hours after catheter angiography, these values increased to 91.6% for the arterial path, 100% for the venous path, and 95.9% for both paths.
Conclusions: The pulse oximeter can display the pulse curve immediately (1 hour) after angiography and indicate pulse improvement at 12 hours maximally following an angiography. In this case, heparin alone may be used instead of thrombolytic agents.

Keywords: Pulse Oximeter, Pulse Improvement, Angiography

1. Background

Pulse oximetry is a noninvasive procedure that measures the rate of hemoglobin molecules combined with oxygen as a percentage (e.g., a normal rate is 95% - 97%). Rates less than 90% indicate a serious issue (1). Pulse oximetry was first used to monitor anesthesia in 1974 (2). The pulse oximeter is a device used to measure the percentage of O_2sat in human arterial blood. It shows wave variations in blood volume per a specified unit of time, which are created by changes in the infrared absorption of the transluminant tissue floor. Although these waves are very similar to pressure waves recorded from arteries, they reflect changes in the blood volume of the tissue floor (3). The pulse oximeter waves recorded from fingertips are very similar to Doppler flow waves recorded from radial arteries and are, in fact, reflections of the Doppler waves. These provide useful information on blood circulation and blood volume changes in the cardiac cycle (2) and confirm the existence of a pulse.

The pulse oximeter displays not only O_2sat but also changes in the light absorption of the tissue floor (4, 5) and along various wavelengths (660 and 940 nm) using oxygenated hemoglobin (2). It also obtains waves from tissue with a supplying artery that is not easily accessible (3). Other tissues, including bone, connective tissue, and venous blood, are also photo-absorbent, which can affect emitted signals. However, while the arterial components of the signal are pulsatile, photo-absorption by other tissues is relatively stable, and a series of pulsatile components are used to specifically estimate the arterial O_2sat (6, 7), along with signals emitted from arterial blood (5, 8).

The mean O_2sat in healthy infants is 97% - 99% (SDs2: 95% - 96%) at sea level, which may be lower in neonates and younger infants (93% - 100%) (9). This percentage may also be lower at very high altitudes (more than 3,000 m) and reach 91% - 98% (10). Pulse oximeter signals have been used to identify hypovolemia and to survey peripheral perfusion and low perfusion states in various studies, including studies to assess muscular blood circulation in both healthy and sick neonates (11-21). The pulse oximeter has also been used successfully to block the sympathetic system and peripheral neuropathy while screening for congenital cardiovascular diseases in asymptomatic neonates and premature newborns (22-29). In the present study, the predictive value of pulse oximetry for improving the arterial pulse after angiography was investigated. It was hypothesized that if the pulse oximeter could display the pulse and O_2sat curve after completion of an angiography and hemostasis at the puncture site, there would be a high probability of pulse improvement at a maximum of 12 hours after the procedure, thereby removing the need for administration of thrombolytic drugs.

2. Objectives

If the pulse oximeter is capable of displaying the pulse curve and O_2sat at completion of an angiography and the hemostasis of a puncture site, the odds of pulse improvement at maximally 2 hours is high, and there would be no need for the use of thrombolytic drugs. The objective of this study was to determine if this hypothesis is correct.

3. Patients and Methods

This multi-center study involved 467 4-day-old to 12-year-old patients at Afshar hospital in Yazd, Imam Hossein hospital in Isfahan, and the Pediatric hospital in Bandar Abbas and was conducted between January 2012 and January 2016. The study group consisted of 12-year-old or younger children who required angiographies for various reasons, including patients undergoing diagnostic angiography or those who were undergoing an intervention. These angiographies were performed through the arterial path, venous path, or both paths. The posterior malleolar pulse or dorsalis pedis pulse were examined at 1 hour after the completion of each angiography in the organ (leg) that had been punctured. When a pulse was not felt manually, the patient was included in the study. Patients with weak pulses detected manually were excluded from the study, along with patients with symptoms of critical organ ischemia or those taking thrombolytic drugs.

In the study group, pulse oximetry was used to identify pulse curves. If the pulse oximeter could display a weak pulse curve immediately (1 hour) after angiography, the extremity pulse should improve at 6 hours or maximally at 12 hours after angiography and be palpable. However, if the pulse oximeter could not display a pulse curve, the pulse could not be palpated at either 6 or 12 hours after angiography. For all patients whose pulses could not be felt and who had no symptoms of critical ischemia of the extremities, heparin infusions were started at 17 U/kg and continued for at least 12 hours. On these patients, pulse oximetry of the punctured extremities was performed immediately (1 hour) after angiography, and the intended extremity was immobilized for a minimum of 10 minutes to avoid parasite wave recordings by the pulse oximeter and to ensure that pulse curves with either weak or strong ranges could be plotted to determine O_2sat values. In these cases, the pulse oximeter was rendered positive. Finally, the pulse of the punctured extremity was examined at 6 and 12 hours after an angiography, and the information pertaining to each patient was recorded. Then, Q-Cochran and McNemar tests were used to analyze the data.

4. Results

The pulse oximeter displayed the pulse of 319 of the patients during the first hour after catheter angiography. During the sixth hour after catheter angiography, 262 of the patients had palpable pulses. There were 148 patients for whom the pulse oximeter displayed no pulse, and 8 patients had palpable pulses 6 hours after angiography (Table 1). The Q-Cochran and McNemar tests indicated that pulse oximetry has good predictive value for pulse improvement at hour 6 ($P < 0.001$). If the patients were divided into two groups (those less than one year old and those more than one year old), pulse oximetry had good predictive value for pulse improvement at hour 6 for both groups. For the infants under one year, 22 patients displayed pulses at hour 1, and 18 of these patients displayed pulses at hour 6. Of the 11 patients for whom the pulse oximeter could not display pulses at hour 1, only one infant had a palpable pulse at hour 6 ($P < 0.001$). In the age group over one year old, 297 patients displayed pulses through the pulse oximeter, and 244 of these patients had palpable pulses at hour 6. Of the 137 patients for whom the pulse oximeter did not display a pulse, only 7 patients had palpable pulses at hour 6 ($P < 0.001$) (Table 2). Furthermore, 304 of 319 patients for whom pulses were displayed by the pulse oximeter at hour 1 had palpable pulses at hour 12. Of the 148 patients for whom the pulse oximeter did not display a pulse, only 13 patients had palpable pulses at hour 12 ($P < 0.001$) (Table 3). Consequently, the pulse oximeter has good predictive value for pulse improvement at 12 hours after catheter angiography

($P < 0.001$) for both the over-one-year group and the under-one-year group ($P < 0.001$) (Table 4).

The arterial path was used for angiography in 145 patients while the pulse oximeter displayed the pulses of 96 of these patients immediately after catheter angiography. Of these 96 patients, 73 had palpable pulses at hour 6, while 23 had no palpable pulses. In the follow-up at hour 12, it was observed that of these 23 patients, only 8 had no pulse at hour 12. The venous path was used for angiography in 66 patients. The pulse oximeter displayed the pulses of 50 of these patients immediately after catheter angiography. Of these 50 patients, 45 had palpable pulses at hour 6, while 5 had no palpable pulses. During the hour 12 follow-ups, all 5 patients had palpable pulses at hour 12. Both the arterial and venous paths were used for angiography in 256 patients. Of these patients, 173 had palpable pulses displayed by the pulse oximeter immediately after catheter angiography. Of these 173 patients, 144 had palpable pulses at hour 6, and 29 had no palpable pulses at this hour. During the 12 hour follow-up, only 7 of these 29 patients had no palpable pulses at hour 12. Thus, pulse oximetry has good predictive value for both the arterial and venous paths as well as the mixed path at hour 6 after catheter angiography ($P < 0.001$) and at hour 12 after catheter angiography ($P < 0.001$). The odds of pulse improvement in children at 6 hours after angiography was 76% if the arterial path was used, 90% if the venous path was used, and 83.2% if both paths were used, while the overall percentage was 82.1%. The odds of pulse improvement at hour 12 after catheter angiography were 91.6% if the arterial path was used, 100% if the venous path was used, and 95.9% if both paths were used, while the overall percentage was 95.2%.

5. Discussion

Pulse oximetry is a monitoring technique used for any traumatized or critically ill patient. Its use is obligatory intraoperatively in many countries (2). This study found that pulse oximetry has good predictive value for pulse improvement at both hour 6 and hour 12 after angiography, for children until the age of 12 years. Additionally, the pulse oximeter is capable of predicting pulse improvement in all paths used for angiography.

In a study by Kwon et al. the ankle brachial index (ABI), pulse oximetry, and CT angiography were performed on 49 patients with lower extremity arterial disorders. These patients were divided into three groups: group one consisted of patients with critical ischemia of the extremities, group two consisted of patients with claudication, and group three consisted of patients who were asymptomatic. In this study there was statistically significant correlations between sensitivity, specificity, and positive and negative predictive values between groups one and two, on whom open and endovascular surgeries were performed, and group three or the conservative group. Additionally, there was a significant correlation between pre-SpO_2 and pre-ABI in groups one and two and in the marked and unmarked groups (group three). Thus, pulse oximetry, which is similar to ABI, is a useful, simple, and noninvasive device for screening peripheral artery disease (30).

In this study, the pulses of 23 of the 145 patients for whom the arterial path was used during angiography were not palpable at hour 6, although pulses were shown by the pulse oximeter immediately after angiography. However, only 8 of these 12 patients had no palpable pulse at hour 12 after angiography. Therefore, the pulse improved in 15 of these patients, which may be attributed to arterial spasms that improve over time. For these patients, heparin infusions may have prevented blood clot formation or thrombosis. Moreover, the arterial pulse was not palpable in 66 patients immediately after angiography, despite the use of the venous path. This could be due to nicking of the artery adjacent to the femoral vein by the needle tip during repeated attempts at phlebotomy, which possibly led to arterial spasms that resolved over time. Pain is another factor that can result in vasoconstriction of the peripheral arteries (31). All 50 patients in this group, whose pulses were displayed by the pulse oximeter immediately after angiography, had palpable pulses at hour 12 after angiography, and heparin infusions prevented thrombosis. Of the 29 patients for whom both the arterial and venous paths were used for angiography, no palpable pulses were detected at hour 6 after angiography, although the pulse oximeter displayed pulses immediately after angiography. However, over time and with continuous heparin infusions, only 7 of these 12 patients had no palpable pulse at hour 12, while pulses improved in the remaining patients. Since the most probable cause of peripheral hypo-perfusion in critically ill patients is vasoconstriction (32), the cause of impalpability of the pulse in many cases after angiography is vascular spasms when the vessel is not completely occluded. In this study, although digital palpation could not palpate the pulse, weak blood flow in the extremities was detected by the pulse oximeter, and these waves produced low signals (4). This indicates that if the process of coagulation through heparin infusion during vascular spasms is inhibited, blood flow should return to the extremities as the spasms resolve, resulting in no need for thrombolytic drugs, such as heparin or TPA, and thereby negating the risks associated with these drugs.

In a study by Lima et al. a peripheral perfusion index of less than 1.4 can diagnose abnormal perfusions in critically ill patients. These changes correspond to clinical signs of perfusion changes and may reflect therapeutic interven-

Table 1. Palpable Pulse at 6 Hours After Angiography Based on the Presence of a Pulse Curve Plotted by the Pulse Oximeter Immediately (1 Hour) After Angiography

Pulse Oximeter Reaction to the Pulse at 1 Hour After Angiography	Palpable Pulse		Total
	Presence of Pulse	Absence of Pulse	
Displayed	262	57	319
Not displayed	8	140	148
Total	270	197	467

Table 2. Palpable Pulse at 6 Hours After Angiography Based on the Presence of a Pulse Curve Plotted by the Pulse Oximeter Immediately (1 Hour) After Angiography, According to Age Group

Age, y	Palpable Pulse		Total
	Presence of Pulse	Absence of Pulse	
≤ 1			
Pulse curve displayed by pulse oximeter	18	4	22
Pulse curve not displayed by pulse oximeter	1	10	11
> 1			
Pulse curve displayed by pulse oximeter	244	53	297
Pulse curve not displayed by pulse oximeter	7	130	137
Total (270)	197	267	

Table 3. Palpable Pulse at 12 Hours After Angiography Based on the Presence of a Pulse Curve Plotted by the Pulse Oximeter Immediately (1 Hour) After Angiography

Pulse Oximeter Reaction to the Pulse at 1 Hour After Angiography	Palpable Pulse		Total
	Presence of Pulse	Absence of Pulse	
Displayed	304	15	319
Not displayed	13	135	148
Total number	317	150	467

Table 4. Palpable Pulse at 12 Hours After Angiography Based on the Presence of a Pulse Curve Plotted by the Pulse Oximeter Immediately (1 Hour) After Angiography, According to Age Group

Age, y	Palpable Pulse		Total
	Presence of Pulse	Absence of Pulse	
≤ 1			
Pulse curve displayed by pulse oximeter	21	1	22
Pulse curve not displayed by pulse oximeter	1	10	11
> 1			
Pulse curve displayed by pulse oximeter	283	14	297
Pulse curve not displayed by pulse oximeter	12	125	137
Total (317)	150	467	

tions for improving peripheral perfusion (2). Since the patients under study sustained perfusion impairment in the punctured extremities and in the cases for which the pulse oximeter could detect weak pulses, the O_2sat value ranged from 85% - 95%. This is because the pulse oximeter estimates O_2sat based on the difference between light absorption by oxygenated hemoglobin and reduced hemoglobin, which is directly correlated to the tissue perfusion rate (2). Therefore, O_2sat could be indicated by a pulse oximeter and correlate to the wave range recorded by the pulse oximeter. This would be an interesting topic for future research.

5.1. Conclusions

Pulse oximetry can predict pulse improvements after angiography in children aged 12 years or less. This property of pulse oximeters is true for various types of angiography applied through arterial, venous, or both types of paths and for cases that show no signs of critical ischemia where the pulse oximeter is able to display the pulse curve immediately (1 hour) after angiography. It can also indicate pulse

improvement to a maximum of 12 hours after angiography. In these cases, heparin should be used instead of thrombolytic agents.

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