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Can We Predict the Width of the Infarct Area in Patients with Acute Ischemic Stroke Using Near Infrared Spectrophotometry?

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Abstract

Background and Purpose: The purpose of this study to determine whether an association exists between near infrared spectrophotometry (NIRS) measurements and affected brain tissue by using NIRS to measure cerebral oxygenations in patients brought to the emergency department with acute ischemic stroke (AIS).

Methods: Thirty-one patients diagnosed with ischemic stroke at diffusion weighted magnetic resonance imaging (MRI) of the brain, aged or over, with no history of ischemic or hemorrhagic stroke and diagnosed at the Recep Tayyip Erdoğan University Education and Research Hospital emergency department, Turkey, were included in the study. Patients with foci of intracranial hemorrhage at cranial computerized tomography (CT) of the brain and no ischemic area identified at brain diffusion MRI were excluded. Cerebral saturation was recorded after being measured for at least 10 min with an INVOS 5100C cerebral/somatic oximeter (Covidien).

Results: Mean age of the 31 patients presenting to the emergency department with AIS was 76.32 ± 10.26. Sixteen (51.6%) were female. Mean Glasgow Coma Score (GCS) was 12.68 ± 3.16. Mean oxygenation values of the ischemic areas in these patients were 57.03 ± 9.03 (min: 40, max: 81), while the mean measurement from areas with no cerebral changes was 67.13 ± 9.64 (min: 54, max: 89) (p<0.001). Mean dimension of the ischemic areas visualized at diffuse MRI was 979.77 ± 635.85 mm2 (min: 43, max: 2180). A positive moderate correlation was observed between ischemic area dimensions and cerebral oximeter values for those areas (r=0,597, p=<0.001). The linear regression model established between patients' ischemic area diameters and level of decrease in cerebral oxygenations revealed a fall in cerebral oxygenation of 5.945 + (0.005 x infarct area (mm2)).

Conclusion: We conclude that that greater the fall in cerebral oxygenation levels the greater the dimensions of the ischemic area. NIRS may be a method that can be used in predicting width of infarct area in patients with AIS.

Key words: Acute Ischemic Stroke, Near Infrared Spectrophotometry, Infarct Area

Introduction

Acute ischemic stroke (AIS) is a disease that leads to death and permanent disabilities, and that must therefore be recognized and treated quickly[1,2]. Emergency departments are places to which these patients present first and where care and treatment plans are prepared. The aim during emergency care is to assess cerebral perfusion and to reduce potential neuronal injury to a minimum[3]. Near infrared spectrophotometry (NIRS), which first entered in to clinical use in the assessment of cerebral perfusion during cardiac surgery in the 1970s, has today become the most effective method of observing cerebral tissue oxygenation[4]. NIRS has the potential to assess cerebral blood volume and saturation and oxy- and deoxyhemoglobin concentrations in patients with AIS in a non-invasive manner. In addition to ease of bedside use, the fact that it is non-invasive and not user-dependent permits the assessment of brain oxygenation in patients with AIS in the emergency department[5].

NIRS has recently begun being used in various fields, such as neurological observation after trauma and surgery and in resuscitation[6-8]. NIRS measures mixed venous/arterial oxygen saturation of the cerebral cortex from the frontal lobe of the brain. Venous oxygen saturation is a marker of local tissue oxygen consumption, and therefore of oxygen distribution and perfusion. A typical NIRS monitor has a light source attached to the probe and one or more photo-detectors and various distances on the other side to the light source. The probe is applied to the region to be measured. Rays reflected by the light source are collected in the photo-detectors. The difference between oxygenized and deoxygenized hemoglobin absorption is measured mathematically and information can be obtained concerning tissue oxygenation. Photo-detectors close to the light source (approximately 3 cm away) receive superficial light rays (from skin, bone and fatty tissue), while the more distant photo-detectors (approximately 4 cm away) perceive light rays from the skin (both from extracranial tissue and from brain tis-

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sue). Since the light absorption wavelengths of oxy- and deoxyhemoglobin are different, calculations can be performed between the emitted and received infrared light rays[9]. This makes it possible to assess tissue oxygenation.

The purpose of this study was to assess whether or not there is an association between cerebral oxygen saturation and width of ischemic area in patients with AIS.

MATERIALS-METHODS

Study design

Following receipt of Recep Tayyip Erdoğan University ethical committee approval, the study was performed at the Recep Tayyip Erdoğan University Rize Education and Research Hospital Emergency Department. Our hospital is a tertiary health institution according to applicable conditions and criteria in Turkey, and the emergency department serves an average of 150,000 patients a year.

Patient characteristics

Age, sex, additional diseases, vital findings and physical examination findings at time of presentation to the hospital emergency department, laboratory test results, imaging tests, in-hospital prognoses and time of onset of symptoms were recorded. Patients aged over 18, with no history of any previous ischemic or hemorrhagic stroke and with AIS diagnosed at brain diffusion MRI were included. Patients with hemorrhage detected at CT of the brain or with diseases such as chronic obstructive pulmonary disease, anemia or hyperbilirubinemia that might affect cerebral oxygenation measurements, and patients aged under 18 were excluded.

Patients with no pathological findings of intracranial hemorrhage at CT of the brain were assessed using diffusion MRI (Figure 1). Ischemic areas identified at diffusion MRI images recorded on the hospital computer system were re-assessed by a specialist radiologist. The ischemic area was calculated as mm^2 from the widest diameter of that area.

Cerebral oximetry measurement

All patients with findings of AIS are cared for on the basis of the guideline prepared for healthcare professionals by the American Heart Association/American Stroke Association. Care for patients in the emergency department is provided by three-member teams, consisting of a physician, a nurse and a paramedic. The nurse monitored and recorded cerebral oxygenation. Cerebral saturation was measured using an INVOS 5100C cerebral/somatic oximeter (Covidien). Oximeter probes were attached to the appropriate areas of the frontal region. The cerebral saturations of patients with ischemic area findings at diffusion MRI were measured over at least 10 min and recorded. Cerebral oxygenation measurements were performed from both the region with ischemic changes and also from the region with no ischemic changes.

Statistical Analysis

Descriptive statistics were expressed as frequency, percentage, mean (mean), standard deviation (SD) and median, minimum (min) and maximum (max) values. Normality was tested using the Shapiro Wilks test. Differences between cerebral oxygenation measurements from the region with ischemic changes and those from the region with no ischemic changes were analyzed using the paired samples t test. Relations between non-normally distributed variables were analyzed using the Spearman correlation test and those between normally distributed variables using the Pearson correlation test. Linear regression analysis was used to determine relations ischemic area diameter and amount of fall in oxygenation between the lobe in which cerebral ischemia occurred and the lobe with a normal perfusion value. $p<0.05$ was regarded as significant. Analyses were performed using SPSS 18.0 (SPSS, Chicago, IL).

Results

Mean age of the 31 patients in the study was 76.32 ± 10.26 years. Sixteen (51.6%) of patients were female and 15 (48.4%) male. Mean systolic artery pressure at time of presentation was 154.52 ± 36.77, and mean Glasgow Coma Score (GCS) was 12.68 ± 3.16. Mean Rankin scores were 3,48 ± 1,8 and mean NIH scores 14,13±8,26. Mortality occurred in 8 (25.8%) cases. Patients' demographic and characteristic features are shown in Table 1.

Mean cerebral oxygenation value measured in the ischemic brain lobe was 57.03 ± 9.03 (min: 40, max: 81). Mean oxygenation value in the cerebral region without ischemic changes was 67.13 ± 9.64 (min: 54, max: 89). A significant difference was determined between oxygenation values measured in the region with ischemic changes compared to that with no such change ($p<0.001$). rSO_2 in the ischemic areas was lower than that in the non-ischemic areas (Table 2).

Table 1: patients' demographic and characteristic features

Characteristics	
Age (mean±SD)	76.32 ± 10.26
Sex F/M	16/15
Systolic BP (mean±SD)	154.52 ± 36.77
GCS (mean±SD)	12.68 ± 3.16
NIH score	14,13±8,26
Rankin score	3,48 ± 1,8
Prognosis ex/alive	8/23

Table 2: Cerebral oximetry values – NIRS measurement values – in patients' ischemic and non-ischemic areas

Variable	NIRS measurement values Mean (SD)	NIRS measurement values Median (min – max)	p
Ischemic area	57.03 (9.03)	57 (40-81)	<0.001*
Non-ischemic area	67.13 (9.64)	64 (54-89)	

Mean fingertip pulse oximetry measured at time of presentation was 97.71 ± 5.17, mean hemoglobin value 13.33 ± 1.67 and mean glucose value 152.42 ± 83.62.

Mean dimension of the ischemic areas seen at diffusion MRI was 979.77 ± 635.85 mm^2 (min: 43, max: 2180). No statistically significant difference was determined between size of patients' ischemic areas and fingertip saturations (p>0.05). A low, negative correlation was determined between size of ischemic area and rSO_2 values in the same region (r= -0,372; p=0.040). Cerebral saturation values in the same region decreased as the size of ischemic area increased. A moderate positive correlation was determined between differences in rSO_2 measurements between ischemic and non-ischemic brain lobes and size of ischemic area (r=0,597, p=<0.001). (Table 3) GCS values decreased as the difference between rSO_2 values for the ischemic area and those for the non-ischemic cerebral region and the areas of the ischemic regions determined at diffusion MRI increased. A negative, low level correlation was determined between these values (r= -0,368; p=0.041).

The linear regression model in which the level of decrease in oxygenation between the lobe in which cerebral ischemia occurred and the lobe with normal perfusion was regarded as a dependent variable, and the dimension of the ischemic area as an independent variable was significant (F=17,407; p<0.001). In the model established, the diameters of patients' ischemic regions explains 35.4% of the decrease in cerebral oxygenation (Adj R^2= 0,354). The linear regression model established was as follows: amount of decrease in cerebral oxygenation = 5.945 + (0.005 x infarct area (mm^2)) (Table 4).

Discussion

A negative correlation was determined in this study between the area of ischemic brain tissue and cerebral saturation.

Table 3: Correlation between ischemic area cerebral oxygenation and size of ischemic area, fingertip pulse oximetry and hemoglobin and glucose values

Variable	Correlation Coefficient	p
Size of ischemic area #	-0,372	0.040*
Fingertip oxygen saturation #	0,037	0.844
Hemoglobin +	0,167	0.369
Glucose #	0,144	0,440

* p<0.05; #Spearman Correlation Test; + Pearson Correlation Test

Table 4: Correlation and regression analysis of patients' rSO2 values

Variables	Spearman Correlation		Linear Regression Model
	p	R	
Dependent Variable (y): Decrease in NIRS measurement values	<0.001	0,597	y= 5,945 + (0.005. x)
Independent Variable (x): Ischemic area size in Diffusion MRI (mm^2)			t= 4,172; p<0.001 F=17,407; p<0.001 R^2=35.4%

Cerebral saturation decreased as ischemic area increased. Although the literature contains various studies in which cerebral functions and neuronal injury were assessed using NIRS[10-12], our study is the first to compare size of the ischemic areas in cerebral tissue in AIS with cerebral saturation measurement values.

NIRS used for the purpose of monitoring cerebral oxygenation, particularly during cardiovascular surgery, has recently begun also being used in various other fields, including resuscitation. In a previous study of ours involving patients with out-of-hospital cardiac arrest we determined that brain oxygenation would be useful in predicting patients' spontaneous circulation. Survival among patients with increases in rSO_2 values at time of presentation to the emergency department greater than 16% in the right lobe and 20% lobe in the left lobe was 9 times higher than that of patients with values less than 16% and 20%, respectively[8]. One study in which cerebral saturation values were associated with mortality was performed by Nardi et al. on patients with sepsis. They reported lower discharge and greater mortality among patients hospitalized in the intensive care unit with low rSO_2 values[13]. If size of infarct area in AIS is thought to be directly associated with mortality, then the determination of a large infarct area in patients with lower cerebral oxygenation in our study and the idea that NIRS may be useful in predicting the size of the infarct region are not unexpected[14-17].

Diffusion weighted MRI has high specificity and sensitivity in showing injury in the brain in the acute period in patients with symptoms of AIS[18,19]. However, this imaging technique is not available in many hospitals and its use in unstable patients at time of diagnosis in the emergency department is limited[20,21]. The low rSO_2 values in this study and the correlation determined between rSO_2 measurement values and size of infarct area support the idea that NIRS can be used as an assistant technique to physical examination and other tests in assessing patients with AIS.

The dimensions of the ischemic area can be estimated with the linear regression model we established. The size of the infarct area can be determined using the increase in the difference between rSO_2 measurements in the ischemic and non-ischemic areas. We think that since the size of the infarct area affects the patient's prognosis, prognosis can be predicted using this technique. Heringlake M et al. reported that short-term mortality increased when the rSO_2 values of patients fell below 51% during cardiac surgery. Although they suggested that several factors can affect mortality, they proposed the level of decrease in rSO_2 values as the main cause. The findings of that study may be associated with the determination of infarct area being correlated with rSO_2 measurements[22].

Limitations

The most important limitations of this study are that it was performed in a single institution and with a low number of patients. However, we think that future studies with larger patient numbers will support our theory. Another limitation is that our patients were not monitored with NIRS in the long term. Patients' cerebral infarct areas in the acute period may not be the same as those in subsequent days. We might have determined lower rSO2 values as the infarct area increased. We think that future studies in which patients are monitored with NIRS for more than 24 h and which compare the results with control brain diffusion MRI will support our findings. Another disadvantage of this study is that we did not classify patients depending on stroke subtypes. Future studies based on subtypes should support our own study.

Conclusion

The level of decrease in cerebral oxygenation measured using NIRS was correlated with size of ischemic area in this study. We conclude that the greater the decrease in the level of cerebral oxygenation, the greater the size of the ischemic area. Although scores such as GCS, NIH and Rankin score are used in the evaluation of patient mortality, we think that rSO2 measurements can also be used in estimating patients' mortalities and ischemic areas.

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