UNIVERSIDADE DA BEIRA INTERIOR
Ciências da Saúde

Feasibility of Near Infrared Spectroscopy in Stroke Patients

Daniel André Gonçalves Torres

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Orientador: Prof. Doutor Miguel Castelo Branco

Co-Orientador: Prof. Doutora Sara Nunes

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To my sister, although we are apart I want you to know that you are always on my mind.

Finally, I would like to thank my parents who have been a constant support and inspiration at all times. Their love and encouragement gave me the strength I needed to accomplish my goals. Thank-You!

Resumo

Near Infrared Spectroscopy (NIRS) é uma forma não invasiva de medir em tempo real a perfusão cerebral. Devido ao seu rápido e recente desenvolvimento existem ainda poucos dados concretos acerca das suas áreas de aplicação. O Acidente Vascular Cerebral (AVC) é um evento de início súbito, de origem isquémica ou hemorrágica, que pode evoluir para rápida perda de funções neurológicas, deixando graves sequelas ou mesmo causando a morte do paciente. O atual diagnóstico de pacientes com AVC é clínico, sendo o diagnóstico definitivo imagiológico (TC/RM). Os objetivos do estudo são portanto:

1) Determinar se, utilizando a tecnologia NIRS, é possível detetar valores de hipóxia num hemisfério cerebral responsáveis pela clínica do AVC, comparativamente com o hemisfério saudável;

2) Determinar se durante o seguimento de pacientes com AVC agudo a utilização de NIRS contribui para a modificação da terapêutica;

3) Comparar o rSO^2 cerebral obtido através da tecnologia NIRS e a SpO^2 periférica obtida com um oxímetro de pulso;

4) Medir os valores de "area under the curve" (AUC), utilizando uma baseline de 60 rSO^2, pois valores abaixo deste estão associados a mau prognóstico;

5) Investigar a possibilidade de aplicação da tecnologia NIRS como nova forma de diagnóstico e seguimento de pacientes com AVC agudo em unidades de cuidados intensivos (UCI).

Palavras-chave

Acidente Vascular Cerebral, AVC, Near-Infrared Spectroscopy, NIRS, rSO^2, SpO^2, Oliguémia, Hiperémia, Circulação vicariante, Oxímetro de pulso, Oxímetro regional, Oximetria em pacientes com AVC,

Summary

Introduction

Stroke is the main cause of death in Portugal. It is a severe pathology with a sudden onset and with a very high demand in both time and money from the families of the affected patients and from health organizations and social services. Inexpensive and practical diagnostic tools that will assist in early detection and treatment are the source of numerous studies.

The physiology behind a stroke is a sudden ischemic event in the brain. Near infrared spectroscopy (NIRS) is a non-invasive mean of measuring cerebral perfusion in real time. Due to its rapid and recent development few data exists about its applicability. Since NIRS detects oxygen levels that are supposedly low due to oligemia in infarcted areas, our study tried to ascertain the significance of NIRS measurements in stroke patients.

Objectives

-Determine which systemic factors influence rSO^2 values.

-Determine NIRS viability in diagnosing and monitoring stroke patients by comparing their values with those of healthy individuals using the reference value of 60 rSO^2.

-Determine if NIRS is capable of influencing therapeutical changes in those monitored.

Methodology

This is a prospective study where we used NIRS EQUANOX® technology with 4 sensors: 2 Frontal 2 supra-auricular to compare cerebral oxygen values of rSO^2 in a control sample of 60 healthy persons from two retirement homes from the geographical area of Covilhã, Portugal and compared them with 128 stroke patients hospitalized in the Centro Hospitalar Cova da Beira (CHCB). We also collected data consisting of: risk factors, imagiological studies and vital signs. The hospitalized patients were monitored twice on the first day and then once daily during the following four consecutive days for a total of five days.

The results were analyzed using SPSS ® software - version 17 for Windows ® and were considered significant at $p < 0.05$. We resorted to the tests of independence Chi-square and Mann Whitney U to analyze the relationships between variables.

Results

Our study revealed that the hospitalized stroke patients had higher rSO^2 values than healthy individuals from retirement homes, and that these higher values decreased along the week they were hospitalized. We also found that the lesion side diagnosed by CT scan had

higher rSO^2 values than the contralateral healthy side. We did not find any association between: stroke risk factors and rSO^2 readings, use of thrombolysis and rSO^2 measurements, the imagiological exams and rSO^2 readings (CT, TU and CU) and no association between age or gender with rSO^2 levels.

Key words

Stroke, Near-Infrared Spectroscopy, NIRS, rSO^2, SpO^2, oligemia, hyperemia, vicarious circulation, pulse oxymeters, regional oxymeters, oximetry in stroke, Ischemical stroke,

Abstract

Background: The physiology behind a stroke is a sudden ischemic event in the brain. Near infrared spectroscopy (NIRS) is a non-invasive means of measuring cerebral perfusion in real time. Due to its rapid and recent development, hardly any data exists about its applicability. Since NIRS detects oxygen levels that are altered due to oligemia in infarcted areas; hence the basis of our study. ***Methods and materials:*** We used NIRS NONIN Equanox sensors to measure 128 stroke individuals from a stroke unit during a five-month period and compared their readings with 60 healthy individuals from a retirement home. ***Results:*** Using 60 rSO2 as reference values to diagnose a stroke, NIRS achieved a Sensibility of 54.22% and a specificity of 74.77%. No association was found between risk factors and rSO2 readings, but it correlated well with peripheral systemic oxygenation(SpO2) drops($p<0.05$). Higher rSO2 readings(4 points) were found on the start of the hospitalization and then declined throughout the week towards the levels of the control group. ***Conclusions:*** With our study we concluded that NIRS technology does not allow ischemic stroke diagnosis. Nevertheless, we found that NIRS detects higher rSO^2 levels in those with acute strokes, probably detecting the acute hyperemia that surrounds oligemic areas.

Keywords

Stroke; Near-Infrared Spectroscopy; NIRS; rSO^2; SpO^2; oligemia; hyperemia; vicarious circulation; pulse oxymeters; regional oxymeters; Oxymeters in stroke; Ischemical stroke;

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List of Acronyms

AUC	Area Under the Curve
AVC	Acidente Vascular Cerebral
CBC	Complete Blood Count
CHCB	Centro Hospitalar Cova da Beira
CT	Computed Tomography
CTA	Computed Tomography Angiography
CU	Carotid Ultrasonography
CVA	Cerebrovascular Accident
DM	Diabetes Mellitus
DVT	Deep Vein Thrombosis
ECG/EKG	Electrocardiogram
Hb	Deoxyhemoglobin
HbO^2	Oxyhemoglobin
INEM	Instituto Nacional de Emergência Médica
LF	Left Frontal Sensor
LS	Left Supra Auricular Sensor
MI	Myocardial Infarction
MRI	Magnetic Resonance Imaging
NIHSS	National Institutes of Health Stroke Scale
NIRS	Near Infrared Spectroscopy
PE	Pulmonary Embolism
RF	Right Frontal Sensor
RM	Ressonância Magnética
RS	Right Supra Auricular Sensor
rSO2	Regional Oxymetry
SpO^2	Pulse Oxymetry
SPSS	Social Sciences Statistical Package
TC	Tomografia Computadorizada
TIA	Transient Ischemic Attack
TU	Transcraneal Ultrasonography
UCI	Unidade de Cuidados Intensivos

Introduction

Definition

The interruption of blood flow can cause cell death or cell lesion due to lack of oxygen and other nutrients and to excess of cellular metabolic waste.

Brain cells are especially susceptible since they, unlike other cells, do not have much regenerative capabilities. The resulting neurological lesion is called a cerebrovascular accident (CVA), or stroke. There are three types of strokes:

Ischemic stroke: a clot or other blockage within an artery leading to or within the brain, by far the most common, accounting for 80% of all events.

Hemorrhagic stroke: has its origin in the rupture of one of the arteries supplying the brain thereby releasing blood and compressing brain structures.

Subarachnoid hemorrhagic stroke: is also caused by the sudden rupture of an artery, but here, the blood instead of being released inside the brain, fills the space surrounding it.

If a person with typical symptomatology of an ischemic stroke has no symptoms after 24hrs, then the event is called a transient ischemic attack (TIA). This frequently precludes a major stroke in 35% of the cases, 50% of which occur within the first year. Prompt treatment and life changing behaviors are needed in order to obtain better results.(2)

Epidemiology

The annual incidence is declining due to more control with anti-hypertensive treatment and dyslipidemia. However, the overall rate of stroke remains high due to the aging of the population.

Although the global incidence of strokes is decreasing, Portugal still has the highest incidence in Europe. According to the Portuguese Stroke society, this pathology is the first cause of death in the country and according to charts from the National Institute of Medical Emergencies (INEM), the number of medical emergency dispatches to attend stroke victims has been on the increase since 2006. The year 2011 was the worst with 2995 cases (figure 1).

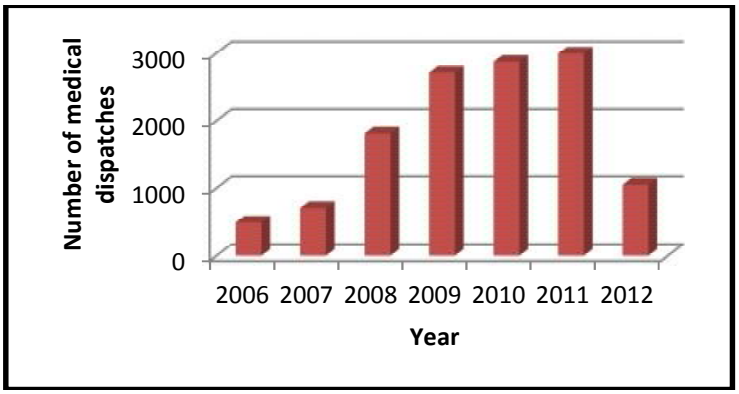

Figure 1. Graphic representation of INEM medical emergency dispatches for acute strokes in Portugal throughout the years(1).

Etiology

The most common problem is narrowing of the arteries caused by atherosclerosis and gradual cholesterol deposition. If the arteries become too narrow, blood clots may be formed. These blood clots can block the artery where they are formed – thrombosis, or they can be dislodged from the vascular wall and become trapped in another smaller artery – embolism (mainly from the heart).

These two phenomenon form the two etiologies of an ischemical Stroke. A thrombosis in-situ can be divided into small vessel thrombosis or large vessel thrombosis (carotid arteries). Small vessel thrombosis is also called a lacunar stroke.

Every area of the brain receives blood supply from specific arteries and it is very rare for stroke patients not to have their cerebral blood flow compromised. Stroke victims may have a rare predisposing condition such as; severe anemia, leukemia, policitemia and exposure to carbon-monoxide. The uncontrollable risk factors are: age 55 or older, gender, race, family history, previous stroke or TIA and Fibromuscular dysplasia. The major controllable risk factors are: high blood pressure, atrial fibrillation, obesity, high cholesterol, diabetes, atherosclerosis, cigarette smoking or exposure to secondary smoke, alcohol abuse, use of birth control pills or replacement hormone therapies, use of illicit drugs such as cocaine and methamphetamines, physical inactivity and cardiovascular disease (heart failure and abnormal heart rhythm).

Many studies have been done to find out what really happens to the brain area that suffered the stroke. It is obvious that this area is ischemic due to oligemia and will evolve into necrosis if circulation is not reestablished. The body's response to this oligemic event is a compensatory hyperemia in the vicarious circulation. In 1981(3) by the use of cerebral angiography and by measurements of the regional cerebral blood flow it was first documented

that acute cerebral infarcts are associated with hyperemic areas; hyperemia being the vascular body's response, which includes dilation and increased blood flow to a hypoxic area. It can be physiological due to physical stress or it can be pathological if it is in response to a disease like a stroke.

A stroke with hyperemic areas has their vascular reactivity impaired and is thought that treatment aimed at reducing blood flow in hyperemic areas might improve prognosis(3).

Symptomatology

The symptomatology depends on the type of stoke, and the size and location of the area affected. Symptoms are usually higher at the beginning and slowly recover through time, although in some cases the deficits are permanent.

At discharge from the hospital, usually 50 % of the initial symptoms have disappeared.

The most common symptom of stroke is sudden weakness of the face, arm or leg, most often on one side of the body.

Other warning signs can include:

- Sudden confusion, trouble speaking or understanding speech;
- Sudden difficulty seeing in one or both eyes;
- Sudden trouble walking, dizziness, loss of balance or coordination;
- Sudden severe headache with no known cause.

Diagnosis

The gold standard for diagnosing a stroke is a CT scan. This exam quickly differentiates a hemorrhagic from an inchemical etiology. An MRI can also be conducted to assist in discerning the amount of damage to the brain, which will be beneficial in predicting recovery.

Other recommended tests are: Electrocardiogram (ECG, EKG), blood tests, such as a complete blood count (CBC), blood sugar, electrolytes, liver and kidney function, and prothrombin time. A carotid ultrasound(CU) scan and a computed tomographic angiography (CTA) can evaluate blood flow through the arteries, searching for plaques that may be in the origin of the stroke(4).

If it is suspected that the stroke may have been caused by a heart problem, then an echocardiogram or Holter monitoring or telemetry test may be done.

In the acute state some strokes may not demonstrate a pathological view in the computed tomography exam, this happens when a stroke is in the in the isodense state. This will later on become visible on the typical hyperdensity image on CT. An imagiological study that is thought to be in the isodense state should not delay prompt treatment (5).

Another result given by the CT scan is Leukoariosis, which is associated with benign aging "white matter disease", as well as strokes and dementia. The mechanisms by which leukoariosis impacts on clinical and cognitive functions are not yet fully understood and studies continue to try to give answers to these changes(6, 7).

There are various stroke scales that can play important roles in prognosis and treatment of stroke patients; such as the Glasgow scale and the National Institutes of Health Stroke Scale (NIHSS). The most commonly used is NIHSS(8). It has implications in whether or not a patient should undergo the main treatment strategy, Thrombolysis, which is the breakdown of blood clots by pharmacological means.

Near Infrared Spectroscopy

History

Initially described in the literature in 1939, Near-Infrared Spectroscopy (NIRS) was first applied to agricultural products in 1968 by Karl Norris and co-workers to help determine the quality of various products. Nowadays we're using (NIRS) as a non-invasive technology that relies on the relative transparency of biological tissues to near infrared light (700-900 nm) to determine tissue oxygenation by using a modified Beer-Lambert Law.

Mechanism

By monitoring absorption at wavelengths where oxy- and deoxy- hemoglobin and cytochrome aa3 differ, it is possible to determine the concentrations of oxyhemoglobin, deoxyhemoglobin, total hemoglobin and oxy-deoxy cytochrome aa3. By calculus, we can determine hemoglobin-O^2 saturation. For the brain, the light absorbing compounds are mainly oxyhemoglobin (HbO^2) and deoxyhemoglobin (Hb), and to a much lesser extent, water and cytochrome aa3.

NIRS versus others oxymeters

Cerebral oximetry and NIRS are identical technologies, except that the former focuses on the measurement of O^2 saturation whereas the latter focuses on the concentrations of oxy- and deoxy- hemoglobin or cytochrome aa3 redox state.

NIRS may also be applied to assess the oxygenation of other organs, such as extremity (muscle), liver, and kidney. In these situations, it is referred to as tissue oximetry or muscle oximetry.

When compared with pulse oximetry (SpO^2), rSO^2 has potential advantages:

- Reflecting a predominately venous measure, rather than arterial only, to evaluate the balance between oxygen delivery and consumption
- Measuring oxygenation specific to the brain beneath the sensor (end-organ perfusion), as opposed to a global measure of oxygenation in the periphery as does SpO^2
- Eliminating the need for pulsatility and flow, as are required with SpO^2

NIRS Equanox technology

The main difference from the recent NIRS equanox technologies and other devices is that equanox technology, by using tree different wave-lengths, can successfully negate the effects of three different biological barriers: skin, bone and Meningis (9, 10). This supposedly makes it far more useful in acquiring correct measurements than their predecessors.

Figure 2. Image representing NIRS NONIN equanox technology.

NIRS reference values

In previous studies (9) patients with $SavO^2$ values bellow 60% had poorer outcomes. Since Equanox sensor measures the same values as $SavO^2$, values below 60% indicate that the patient is already in a state of limited oxygen reserve, and the physician should consult other parameters immediately to avoid profound desaturation that might lead to cerebral injury. Until this date no studies directed at finding reference values for NIRS in stroke patients have been done.

Fieldwork

There are a lot of new studies emerging supporting the use of NIRS technology, in adults(11) in neonates(12, 13) and during a cardiovascular surgery(14); but the use of NIRS in stroke patients has few noteworthy works published.

In stroke individuals, little work has been done and much more is needed until NIRs is an established clinical practice tool. Of note, the work developed by Keller et al(15) with the use of indocyanine green at the bedside of stroke individuals and the work of Fabrizzio Vernieri et al(16) with the use of transcranial ultrasonography and nirs in stroke individuals, are good examples . Articles such as “Cerebral NIRS: How Far Away From a Routine Diagnostic Tool?”(17), prompted this study whose main objective is **to determine the applicability of NIRS in detecting and treating stroke patients.**

Methodology

1.Study design

We conducted a transversal/prospective study with descriptive and analytic components. Preference was given to quantitative analysis so that we could respond to the objectives of the study with valuable statistical information and with less bias.

2. Population

The sample is composed of individuals between the ages of 42 to 97 years residing in the area serviced by the CHCB hospital. We took measurements in the stroke unit during 5 consecutive months with a population size of 128 patients.
In order to participate in the study the patients had to have been admitted to the stroke unit with an ischemical stroke or TIA diagnosis.

Since there are no reference values from previous studies, we needed a control group that had the same age values and that never had a stroke or TIA. Our control sample consists of 60 healthy persons from two retirement homes in the area of Covilhã older than 56 years.

The reason that we have only taken samples from retirement homes is that many of our stroke unit patients come from these institutions and they have populations that are older than at any other locations where we could have performed NIRS measurements.

The participants in the control group had no history of stroke or TIA and were all in a retirement home.

3. Means of Investigation

We used Near Infra red spectroscopy using Nonin Model 7600 regional oximeter and 8000CA sensor with dual emitter and dual detector technology.

Two sensors for each individual were used, two at the frontal cortex comprising of the right and left forehead (RF and LF) and then the same two on each side on the temporal lobe above the ears so we could access a close measure of the middle cerebral artery (RS and LS).

The spO^2 was obtained using a finger sensor with the unit's equipment, Datex ohmeda.

The sensors were reused in different patients since the manufactors state that reutilization in different patients accounts for only 1% variability difference in the measurements taken(2).

4. Data Recovery

Data was collected from July to December 2011. Measurements of both rsO^2 and SPO^2 were taken simultaneously. Two different readings were taken on the first day of admittance and then one reading daily for the next four consecutive days, for a total of six different sets of rSO^2 measurements. Each set of measurements consists of one set of readings of rSO^2 values, one spo^2 and one arterial pressure measurement. The rso^2 values are comprised of four different measures: 2 at the forehead (right and left (RF,LF)) and 2 above the temporal lobe (right and left(RS,LS)). Since we can only plug in two sensors at a time, we did the frontal readings first followed by the temporal measurements. All rSO^2 and SpO^2 readings were taken by the same two professionals. In all, we collected 3072 instant measurements of rSO^2 and 768 measurements of SpO^2 and blood pressure. The two readings from the first day were taken 8 to 12 hours apart. If there was a fluctuating value, three different measurements would then be taken, 10 seconds apart, in order to obtain a medial reading.

Nurses took the arterial pressure measurements and their values were acquired at the computer stations. The values used never deviated more than 30 minutes from when the rso^2 and SpO^2 readings were taken.

Standard monitoring included measurements with a 5-lead continuous electrocardiograph, heart rate, peripheral oxygen saturation, and arterial pressure. The device used to acquire these measurements was the Datex-Ohmeda Patient Monitors. For our study and as part of our unit routine we also obtained the following information for each patient: gender, age, NIHSS and Glasgow scale results, transcranial ultrasound (TU) report, carotid ultrasonography (CU) report and a computed tomography (CT) report. We documented if a patient had experienced Fibrinolysis and if any of the following risk factors were present: dyslipidemia, atrial fibrillation, alcoholism, obesity, diabetes mellitus, if he is a smoker, if the patient is hypertensive and if he had a previous: stroke, heart failure, pulmonary thromboembolism, deep venous thrombosis or a acute myocardial infarction. For our study, we also searched the CT and CU reports to find the following pathologies: Diffuse bilateral stenosis and Leucakariosis.

5. Data statistical treatment

The obtained data was analyzed using both Microsoft Excel ® and software Statistical Package for Social Sciences® (SPSS - Windows version 17.0). At the start, we used a descriptive analysis of absolute frequencies, median and mean (absolute and relative frequencies, and standard deviation). We then tested the normality using Kolmogorov-Smirnov for sample higher than fifty ($n > 50$) and Shapiro-Wilk test for samples under fifty ($n < 50$). If the sample followed a normal distribution we used the Chi-Square test, but since most of our results didn't followed a normal distribution we used the Mann–Whitney–Wilcoxon non parametric test. The null hypothesis" was rejected when the p-value was less than the significance level α of 0.05.

Results

1. Descriptive analysis

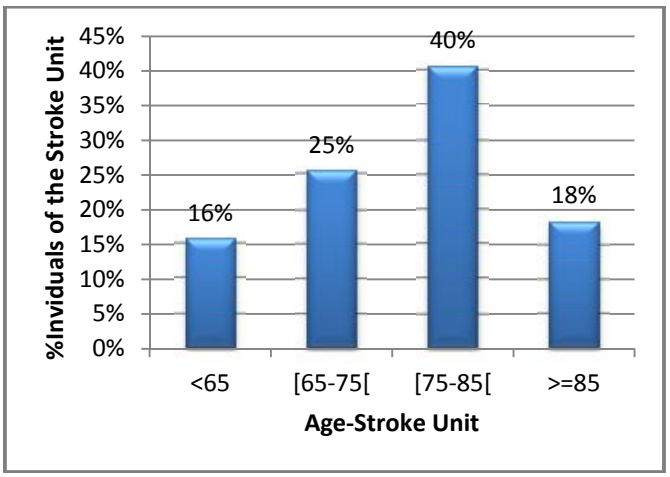

Figure 3. Graphic representation of age in the stroke unit population.

We studied 128 stroke patients during a five month period. The average age was 75 years, with 95% of the population being older than 50 years. In Figure 3, we can see that the most representative age groups are the ones between 65 to 85 years old, comprising 65% of the population.

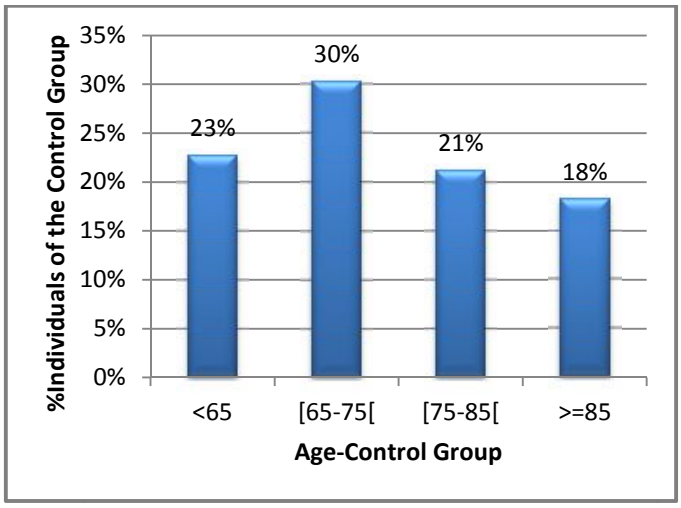

Figure 4. Graphic representation of age in the control group.

Since we had the need for reference values we also conducted measurements on 60 healthy individuals from two retirement homes with an average age of 74 years. On figure 4 we can see that the most representative age classes are the ones between 65 to 85 years comprising 51% of the population.

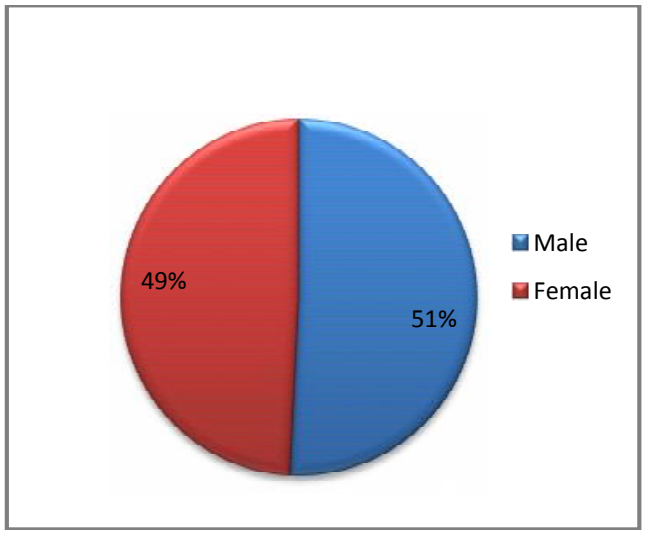

Figure 5. Graphic representation of gender distribution in the stroke unit population

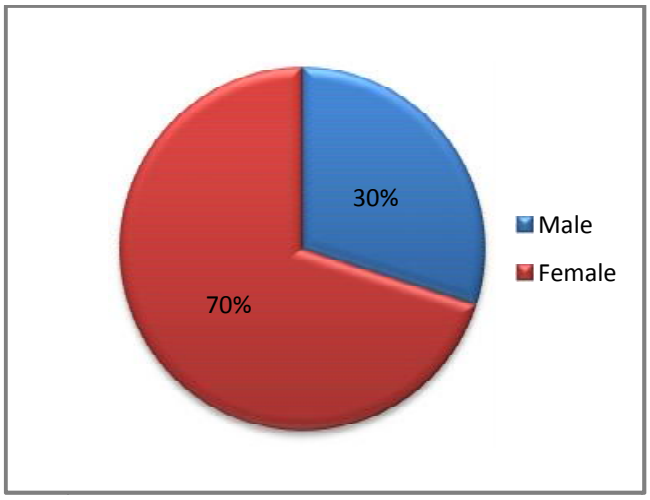

Figure 6. Graphic representation of gender distribution in the control group.

Figure 5 shows us that the gender distribution is similar for the stroke unit, but on the control group (figure 6), we have a female preponderance of 70%.

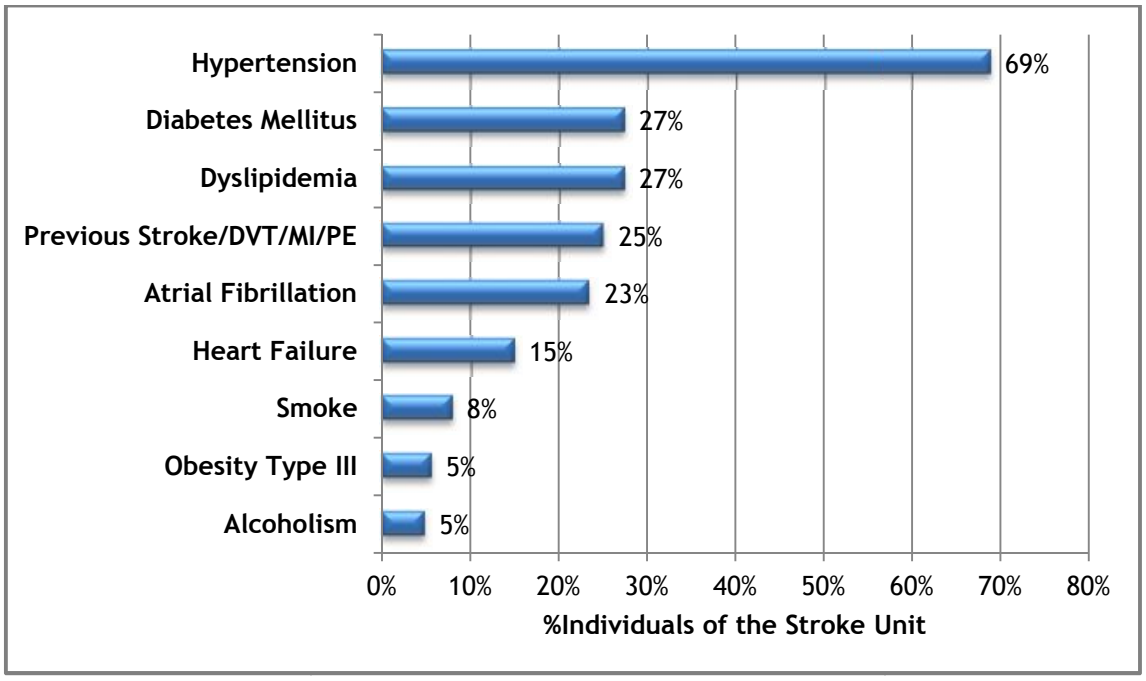

Figure 7. Graphic representation of the prevalence of the makor risk factors among the stroke unit population.

Figure 7 depicts the percentage of individuals from the stroke unit affected by each risk factor. We can see that the most common risk between all individuals was hypertension with 69%. Diabetes, dyslipidemia, previous stroke/DVT/MI/PE and atrial fibrillation were present in one fifth of the population (23-28%). Heart failure was found in 15% of the individuals, 8% of the individuals smoked, and alcoholism and type 3 obesity were found on 5% of the individuals.

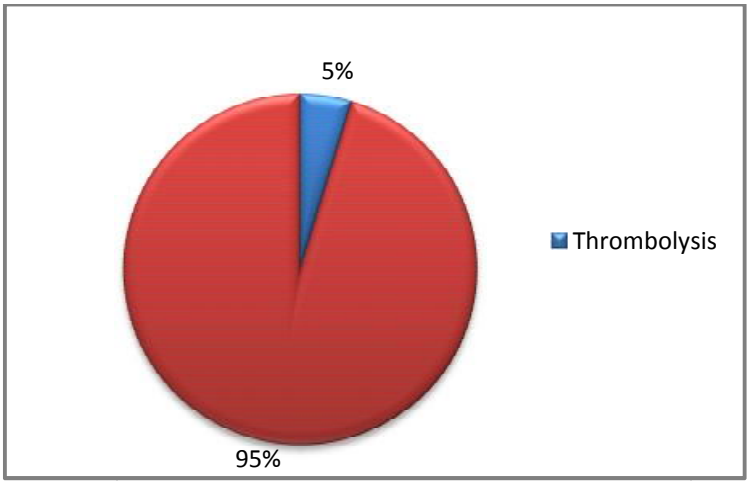

Figure 8. Graphic representation of the percentage of individuals from the stroke unit who had undergone thrombolysis.

As we can see from figure 8, only a 5% of our patients were submitted to Thrombolysis.

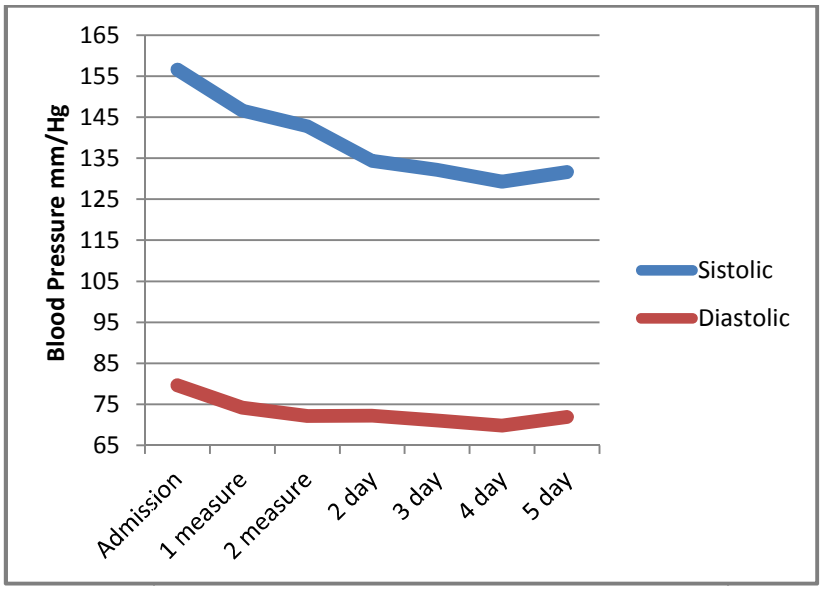

Figure 9. Graphic representation of the arterial pressure variations along the week in stroke patients.

Figure 9 depicts the blood pressure variations of stroke patients along the week . We can see that the values are higher at the beginning and then slowly decrease along the week.

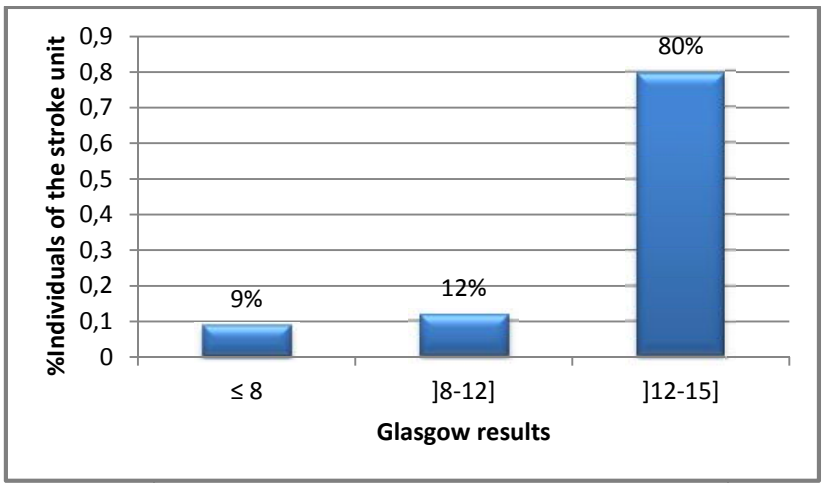

Figure 10. Graphic representation of the percentage of individuals of the stroke unit with their Glasgow result.

By observing figure 10 we can see that 80% of the studied population had a glasgow of]12-15], corresponding to minor brain injury, 12% had a glasgow of]8-12] corresponding to a moderate brain injury and only 9% had a severe brain injury with a glasgow scale under 8.

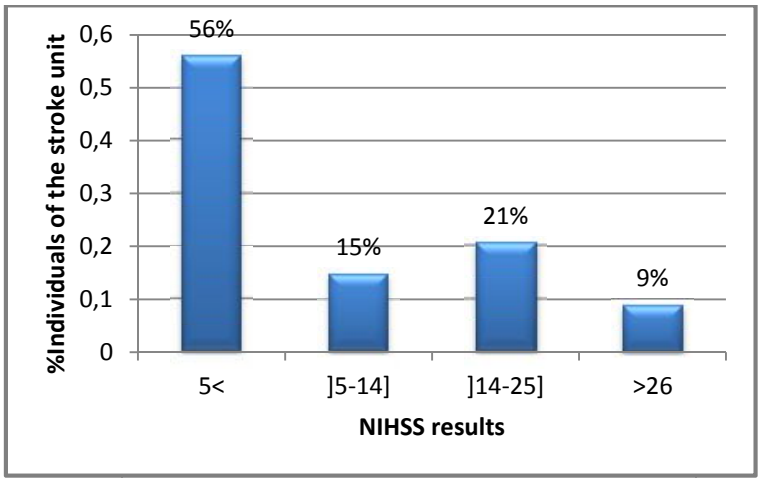

Figure 11. Graphic representation of the percentage of individuals of the stroke unit with their NIHSS results.

By observing figure 11, we can see that 56% had a mild pathology with NIHSS values under 5, 15% had mildly severe pathology with NIHS between 5-14, 21% had severe pathology with NIHSS scores of 14-25 and 9% had a very severe pathology wih NIHSS values above 26.

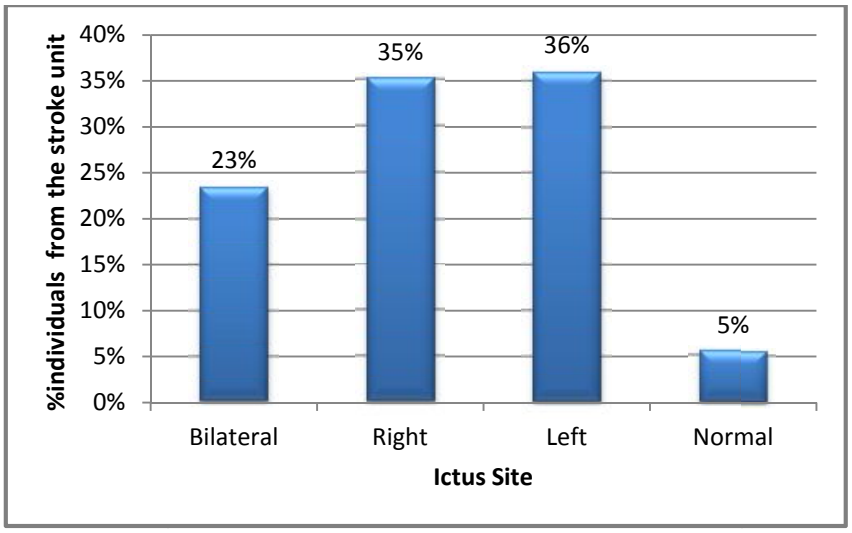

Figure 12. Graphic representation of the results of a CT scan divided by the brain area affected in the stroke unit population.

On figure 12 we can see the results of the CT scan for site of lesions. The lesions on the right and left side had the highest incidence values with 35% of the population each, followed by billateral lesions usually more severe with 23% and finally 5% with normal imagiological scans. Most of the Normal imagiological studies were patients with small strokes that had the sympthology but were on the acute isodense state and therefore with no pathological image.

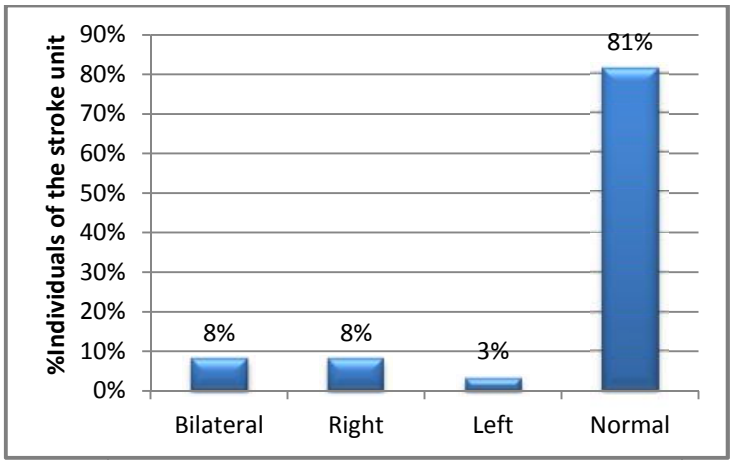

Figure 13. Graphic representation of the results of a TU exam divided by the brain area affected in the stroke unit population.

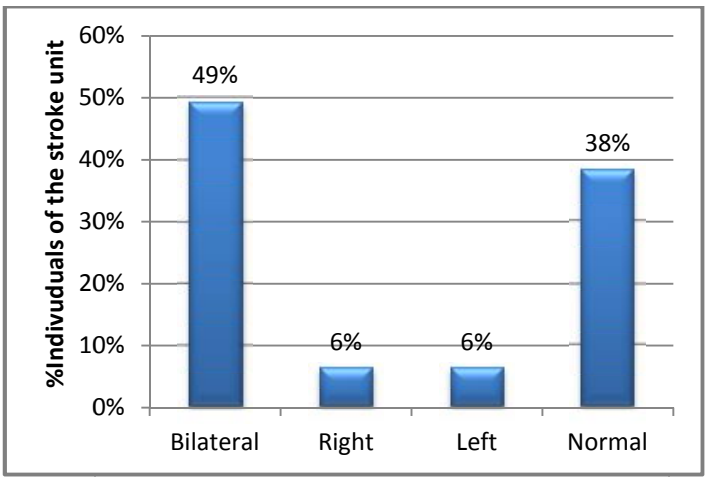

Figure 14. Graphic representation of the results of a CU exam divided by the brain area affected in the stroke unit population.

On our stroke unit every stroke patient was submitted to a CU and a TU. On figure 13 and 14, we can see that on CU, 66% of the population studied presented pathological lesions and 49% were bilateral. On TU we can see that 81% of the population is healthy with only 19% reporting lesions. For reference most of the lesions reported on CU were plaques, stenosis and flow alterations and on TU most reported lesions were flow alterations.

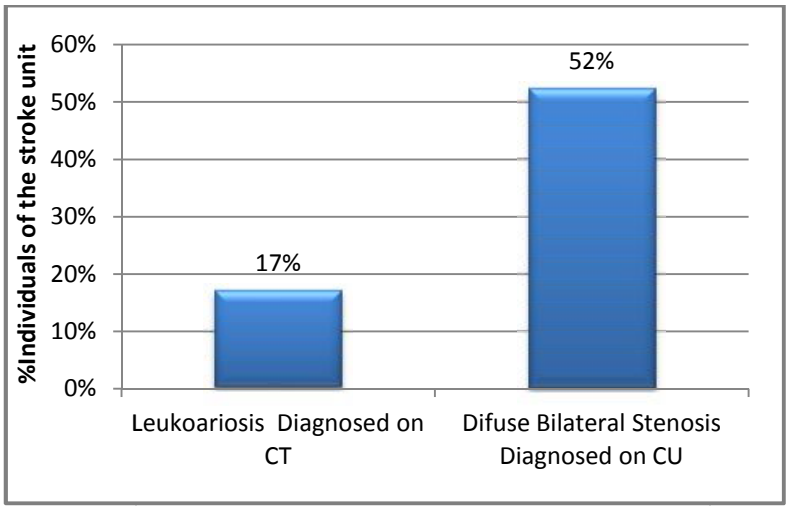

Figure 15. Graphic representation of the percentage of individuals of the stroke unit affected by leukoariosis and difuse bilateral stenosis.

Two commonly reported imagiological results were leokoariosis by CT scan and Diffuse bilateral stenosis reported on CU exam. Figure 15 shows us that 17% of the individuals from the stroke unit were diagnosed with leokoariosis on the CT scan and in 52% of the individuals, we identified diffuse bilateral stenosis on the CU exam.

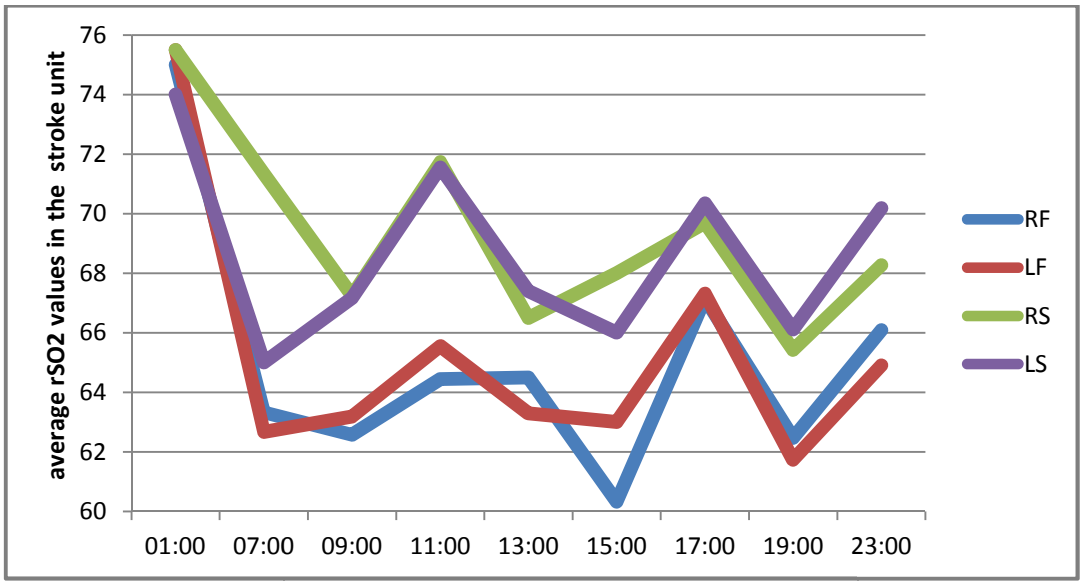

Figure 16. Graphic representation of the average rSO^2 values at different times of the day.

Since we took many readings at different hours of the day we were able to plot figure 16 with the daily rSO^2 variations of the stroke unit population. This graphic ditribution based on 768 time readings, displays rSO^2 values close to each other in the first hours of the morning(1am). But it seems that as the day progresses; the frontal values get further apart from the supra-auricular ones with the latter having higher readings during the rest of the day.

2. Statistical inference

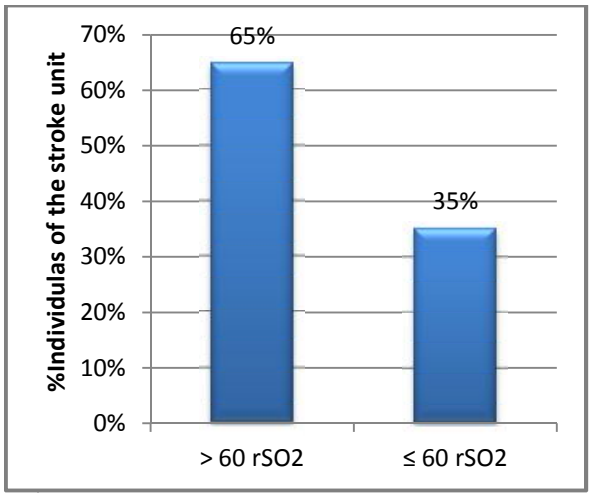

Figure 17. Graphic representation of the percentage of individuals of the stroke unit with values higher and lower than 60 rSO^2.

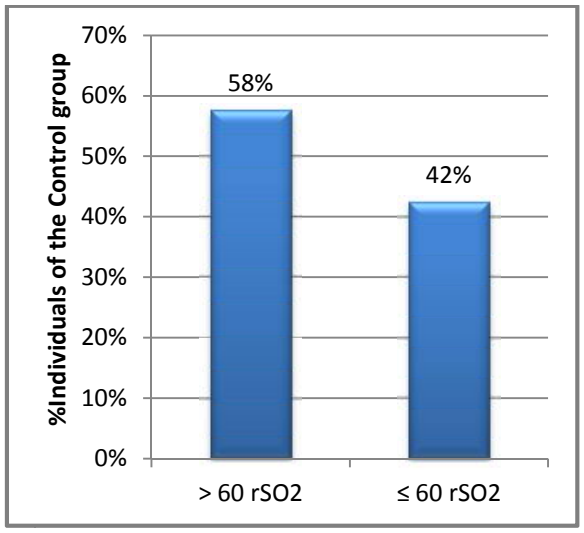

Figure 18. Graphic representation of the percentage of individuals of the control group with values higher and lower than 60 rSO^2.

Table 1. Representation of NIRS specificity, sensitivity and positive and negative predictive values, using 60 rSO^2 as reference.

		Patients below 60 rSO^2		
		Positive	Negative	
NIRS	Test Positive	45	28	Positive Predictive Value 45/(45+28)= 62%
	Test Negative	38	83	Negative Predictive Value 83/(83+38)= 69%
		Sensitivity 45/(45+38)= 54,22%	Specificity 83/(28+83)= 74,77%	

As noted by David et al(9), values of rSO^2 bellow 60 are pathological and prompt evaluation should be undertaken. On figure 17 and 18, we have the percentage of individuals from both the stroke unit and the control group with rSO^2 values below 60. We considered as a positive value any rSO^2 meassurement bellow 60 even if only one of the 4 readings fell bellow the baseline. As can be seen, 35% of the stroke individuals had values compatible with ischemic lesions. Surprisingly, the control group had a higher value (42%) for the same measurements even though they were the healthy population. Thus, when we try to use values bellow 60 rSO^2 for diagnosing an acute stroke considering both the stroke population and the healthy control group, as seen in table 1, NIRS made the correct diagnosis in 128 of 194 individuals and therefore obtained only a 54% sensitivity, and 74% specificity when compared to the 89% sensitivity and 100% specificity of a CT scan.

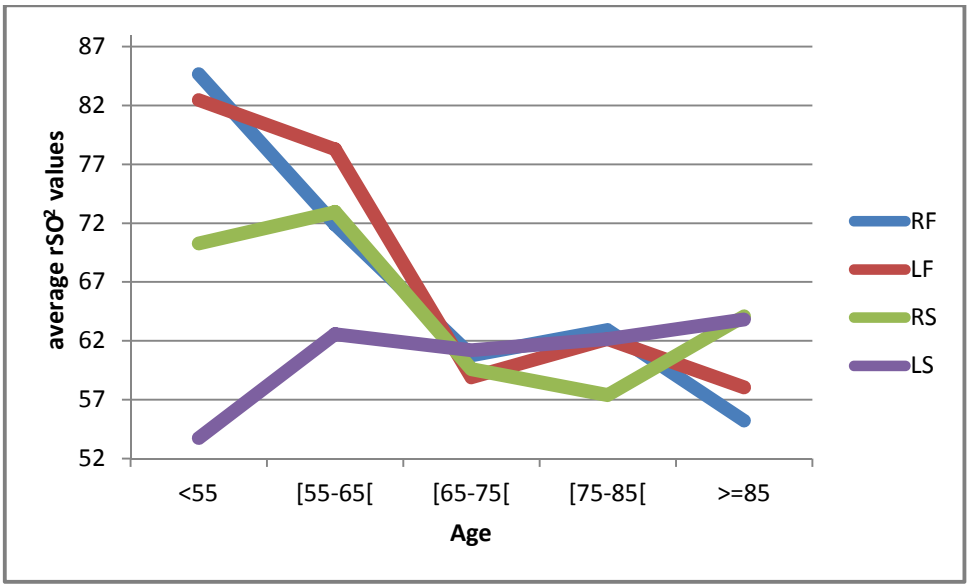

Figure 19. Graphic representation of the average rSO^2 values from the first measurement in the stroke patients distributed by age.

Table 2. Statistical inference between age and rSO^2 measurements, done in the stroke unit population

	p-value: Mann-Whitney U				
	rSO^2				SpO^2
	RF	LF	RS	LS	
Age	0.233	0.325	0.645	0.956	0.01

On figure 19 it seems that as age increases, the average rSO^2 values decrease, but by observing table 2 age does not produce any significant statistical diference in rSO^2 readings (pvalue >0.2) only on SpO^2(p=0.01).

Table 3. Statistical inference between the age in the control group and the age of the stroke unit population.

	p-value: Mann-Whitney U
Age control group VS Age Stroke unit	**0.077**

On table 3 we do not have a statistically significant difference between the age of the control group and the age of the stroke unit. This tells us that the age gap between figure 3 and 4 does not account for bias in the comparisson of the two groups, since they are simmiliar in age.

Table 4. Statistical inference between the relation of the rSO^2 values in each gender in the stroke unit population

	p-value: Mann-Whitney U				
	rSO^2				SpO^2
	RF	LF	RS	LS	
Gender	0.973	0.740	0.609	0.512	0.312

By observing table 4 it seems that gender has no influence on rSO^2 values (p>0.512) or SpO^2 values (p>0.312). Therefore the difference between figure 5 an 6 does not account for different rSO^2 values between the stroke unit and the control group.

Table 5. Statistical inference between rSO^2 values and the different risk factors in the stroke unit population.

	p-values: Mann-Whitney U				
	rSO^2				SpO^2
	RF	LF	RS	LS	
Alcoholism	0.524	0.341	0.196	0.518	0.843
Atrial Fibrillation	0.573	0.357	0.68	0.729	0.539
Diabetes mellitus	0.699	0.607	0.556	0.59	0.987
Dyslipidemia	0.367	0.837	0.356	0.25	0.391
Heart Failure	0.049	0.477	0.825	0.902	0.002
Hypertension	0.886	0.677	0.726	0.717	0.768
Obesity	0.278	0.129	0.199	0.662	0.71
Previus Stroke/ DVT/MI/PE	0.713	0.624	0.227	0.283	0.174
Smoke	0.893	0.781	0.76	0.967	0.203

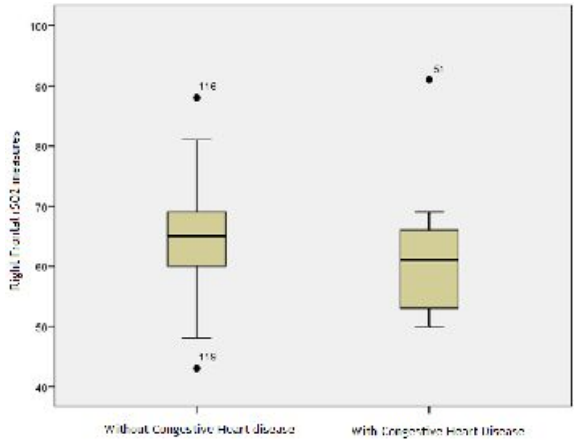

Figure 20. Graphic representation of the rSO^2 values in stroke patients with and without Heart failure.

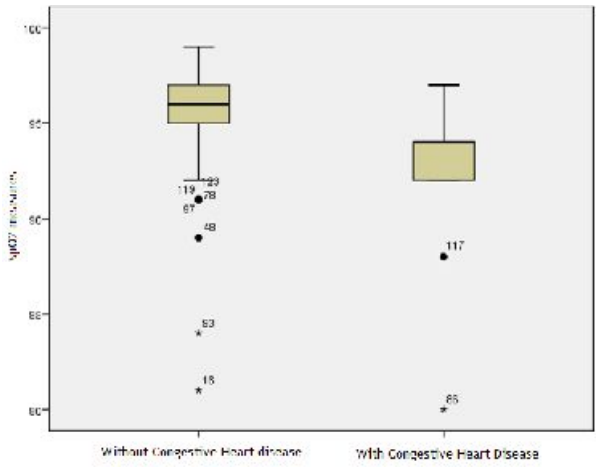

Figure 21. Graphic representation of the SpO^2 values in stroke patients with and without Heart failure.

We tried to find which of the already proven risk factors for stroke influence rSO^2 levels in our stroke patients and we noted that none of the presented risk factors on figure 4 had any influence on average rSO^2 and SpO^2 values, as shown by all the p-values higher than 0.05 on table 5. Only Congestive heart disease presented two significant statistical differences: (p=0.049) for frontal right sensor and (p=0.002) for SpO^2, with both being lower if Congestive Heart disease was present (figure 20 and 21).

Table 6. Statistical inference of rSO^2 values in the stroke unit population between those who underwent thrombolysis and those who did not.

	p-values: Mann-Whitney U				
	rSO^2				SpO^2
	RF	LF	RS	LS	
Thrombolysis	0.7	0.348	0.134	0.141	0.574

On table 6 we can also see that the 5% of the stroke unit patients that underwent thrombolysis had no statistical difference in their rSO^2 and SpO^2 values as compared to those without any intervention.

Table 7. Statistical inference of rSO^2 values in the stroke unit population between those who had Leukoariosis and diffuse bilateral stenosis and those who did not suffer from these pathologies.

	p-values: Mann-Whitney U				
	rSO^2				SpO^2
	RF	LF	RS	LS	
Leukoariosis	0.086	0.155	0.966	0.292	0.222
Difuse Bilateral Stenosis	0.866	0.772	0.148	0.065	0.5

Patients with Leukoariosis and diffuse bilateral stenosis also did not demonstrate any statistically significant difference between their rSO^2 values when compared with individuals not carrying these pathologies. (Table 7).

Table 8. Statistical inference of rSO^2 values in the stroke unit population between those who had reported pathologies on CU and TU and those who did not.

	p-values: Chi-Square test				
	rSO^2				SpO^2
	RF	LF	RS	LS	
CU	0.835	0.917	0.213	0.065	0.843
TU	-0.871	-0.951	-0.771	-0.754	0.339

When comparing the two diferent imagiological studies on table 8 of the RS from CU exam; we can see that none of the other values were statistiacally significant. Therefore,

there are no differences in the values of rSO^2 and SpO^2 in those individuals with or without reported TU and CU imagiological lesions.

Table 9. Statistical inference of the rSO^2 levels and the different lesions sites reported on CT CU and TU exams done in the stroke unit population

	p-value: Chi-Square test				
	rSO^2				SpO^2
	RF	LF	RS	LS	
TU	0.271	0.288	0.569	0.491	0.681
CU	0.895	0.479	0.02	0.156	0.994
CT	0.375	0.542	0.763	0.45	0.45

When comparing the rSO^2 from the different lesions sites diagnosed on each of the imagiological studies presented on table 9 we can say that there is no statisticaly significant difference between them, with the exception of the p=0.02 of RS in CU . Thus it seams that the site of injury does not influence rSO^2 levels.

Table 10. Statistical inference between the Glasgow and NIHSS and the rSO^2 levels in the stroke unit population.

	p-values:Pearsons Correlation				
	rSO^2				SpO^2
	RF	LF	RS	LS	
Glasgow Scale	0.117	0.412	0.764	0.285	0.000
NIH Stroke Scale	0.097	0.028	0.639	0.588	0.311

By observing table 10 we can say, with the exeption of the left frontal sensor readings on NIHSS (p=0.028), that the NIHSS and the glasgow coma scale had no influence in rSO^2 levels.

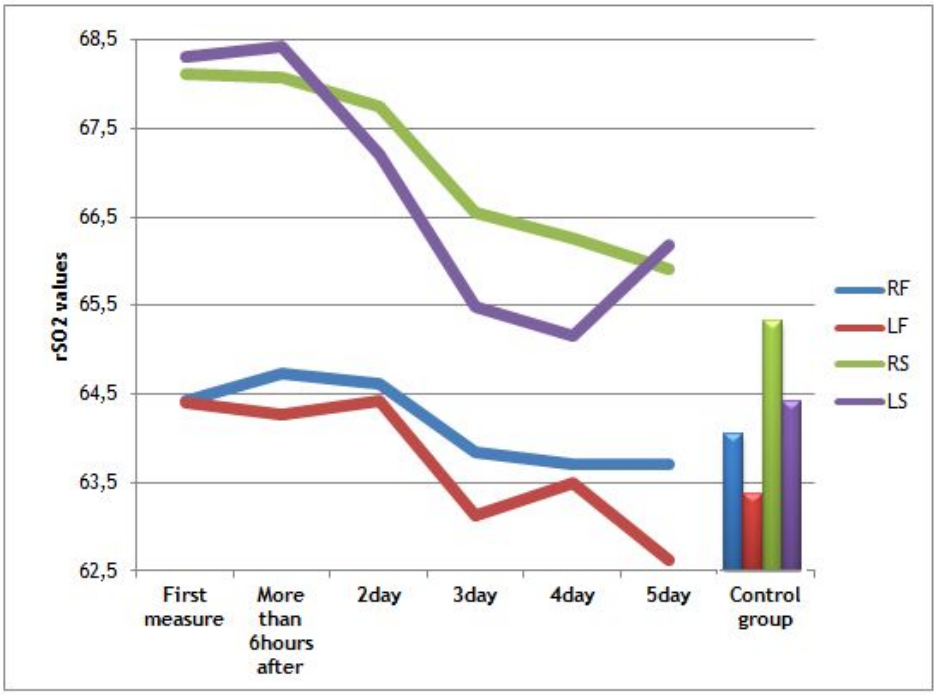

Figure 22. Graphic representation of the average rSO^2 measurements in the stroke unit patients along the week.

Table 11. Statistical inference of the different average rSO^2 levels along the week

p-values: Chi-Square test		
Variation along the week	RF	0.188
	LF	0.037
	RS	0.003
	LS	0.000
Difference between the rSO^2 sensors along the 6 measures	RF vs RS	0.000
	LS vs LF	0.000
	LS vs RF	0.000
	LF vs RS	0.000
	LS vs RS	0.000

Table 12. Statistical inference of the different average rSO^2 levels between the control group and the first measurement of the stroke patients.

p-value: Mann-Whitney U				
	rSO^2			
	RF	LF	RS	LS
Control group VS Stroke Unit first measurement	0.770	0.224	0.010	0.000

Since we followed each patient of the stroke unit for 5 consecutive days we were able to plot figure 22. Here we have represented graphic variations of the average rSO^2 values of stroke patients along the week. At the end we can also see the average rSO^2 values of the control group of healthy individuals. With a total of 3072 measurements it seems that the levels are decreasing with the highest ones being at the beginning of the week and then slowly deacresing to values simillar to those obtained in the control group. The variations of the measurements obtained during the week proved to be statisticaly significant for the stroke unit as demonstrated by table 11; while the difference between rSO^2 levels in the control group and the first measurement of the stroke unit only demonstrated to be statistical significant for the supra auricular sensors as seen in table 12.

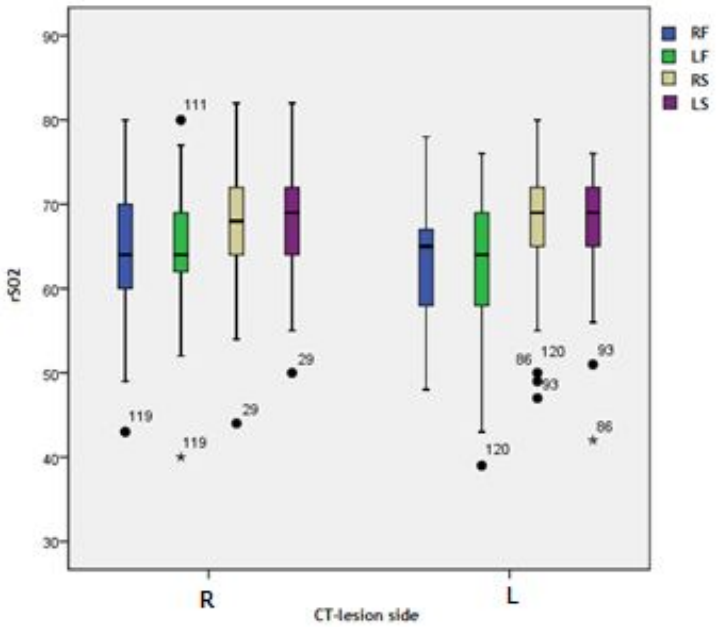

Figure 23. Graphic representation of right and left lesions on CT and their repective rSO^2 levels.

Table 13. Percentage of individuals with higher rSO^2 levels on one side of the brain when compared to the contralateral side in those with a right or left sided lesion detected by a CT scan.

	p-values:Pearsons Correlation		
	Right>Left	**Left>Right**	**Left=Right**
Right lesions-CT	**51%**	**31%**	**18%**
Left lesions -CT	**39%**	**54%**	**7%**

Table 14. Statistical inference between the difference in rSO^2 values in right lesions detected by CT.

p-values: Mann-Whitney U		
Right lesions and First rSO^2 Measure	**RF VS LF**	**0.351**
	RS VS LS	**0.619**

Table 15. Statistical inference between the difference in rSO^2 values in left lesions detected by CT.

p-values: Mann-Whitney U		
Left lesions and First rSO^2 Measure	**RF VS LF**	**0.624**
	RS VS LS	**0.964**

When analysing figure 23 we can see that the supraauricular sensors have almost the same measurements between them, whether it is a left hemispherical lesion or a right, but the same is not true for the frontal sensors. It seems that the hemispherical side injured has the frontal sensors detect higher measures of rSO^2 in 51% and 54% of the patients opposed to the healthy hemisphere which only had higher levels of rSO^2 in 31% to 39% of the patients (table 13). Although it appears as if we have a higher probability of having higher measures of rSO^2 in the cerebral hemisphere damaged by the stroke, tables 14 and 15 tell us that there were no statistical differences between rSO^2 values in those having a hemispherical lesion diagnosed on CT when comparing each sensor with it's contralateral side.

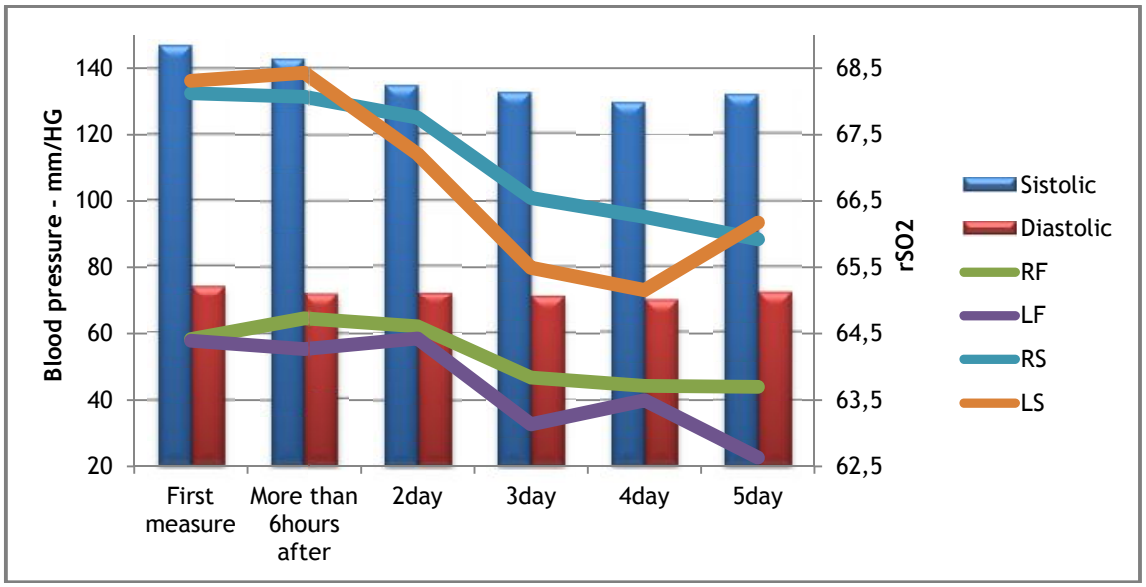

Figure 24. Graphic representation of the weekly variation in rSO^2 levels and blood pressure measurements .

Table 16. Statistical inference between the rSO^2 levels along the week and arterial pressure measurements in the stroke unit population.

		p-value_ Pearson Correlation	
		Systolic	Diastolic
First Day First Measure	RF	0.786	0.817
	LF	0.791	0.702
	RS	0.863	0.975
	LS	0.989	0.817
First Day Second Measure	RF	0.09	0.63
	LF	0.108	0.078
	RS	0.77	0.351
	LS	0.08	0.217
Second Day	RF	0.115	0.147
	LF	0.028	0.04
	RS	0.009	0.319
	LS	0.007	0.117
Third Day	RF	0.482	0.53
	LF	0.689	0.69
	RS	0.231	0.986
	LS	0.88	0.472
Fourth Day	RF	0.219	0.894
	LF	0.673	0.871
	RS	0.604	0.606
	LS	0.336	0.978
Fifth Day	RF	0.589	0,281
	LF	0.35	0.038
	RS	0.358	0.412
	LS	0.175	0.892

By observing figure 24 we can see that both the rSO^2 and blood pressure measurements have decreasing levels throughout the week. We made a Pearsons correlation test to determine if blood pressure is the responsible factor for the weekly rSO^2 variation. The results are shown on table 16, where we can see that there was no correlation; therefore telling us that blood pressure is not the responsible factor for the rSO^2 variations along the week.

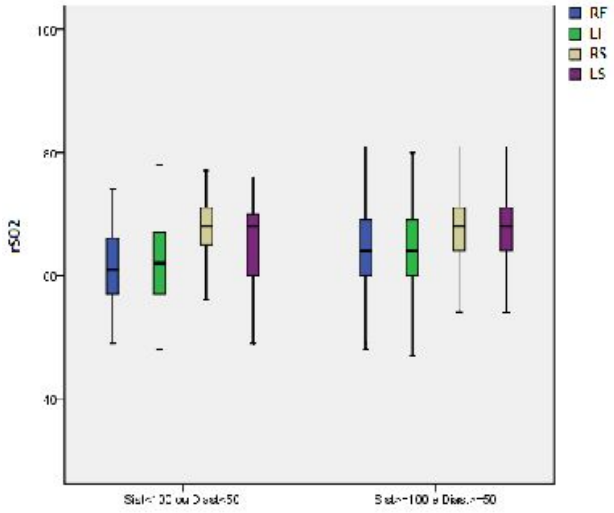

Figure 25. Graphic representation of the rSO^2 levels in those with blood pressure levels higher and lower than 100 systolic and 50 diastolic in the stroke unit population.

Table 17. Statistical inference between the difference in rSO^2 levels in those with blood pressure levels higher and lower than 100 systolic and 50 diastolic in the stroke unit population.

	p-values: Mann-Whitney U			
	rSO^2			
rSO^2 levels in those with	RF	LF	RS	LS
Sistolic <100 mm/Hg or Diastolic <50 mm/Hg	0.024	0.134	0.681	0.112

By analyzing figure 25 we were trying to ascertain if extreme measures of blood pressure could influence rSO^2 levels. Since our hospital stroke unit acts on high blood pressure values we could only find patients that presented hipotensive measurements. By observing table 17 we can see that lower blood pressure measurements do not influence rSO^2 levels, except for the significant result observed in the right frontal sensor(p=0.024).

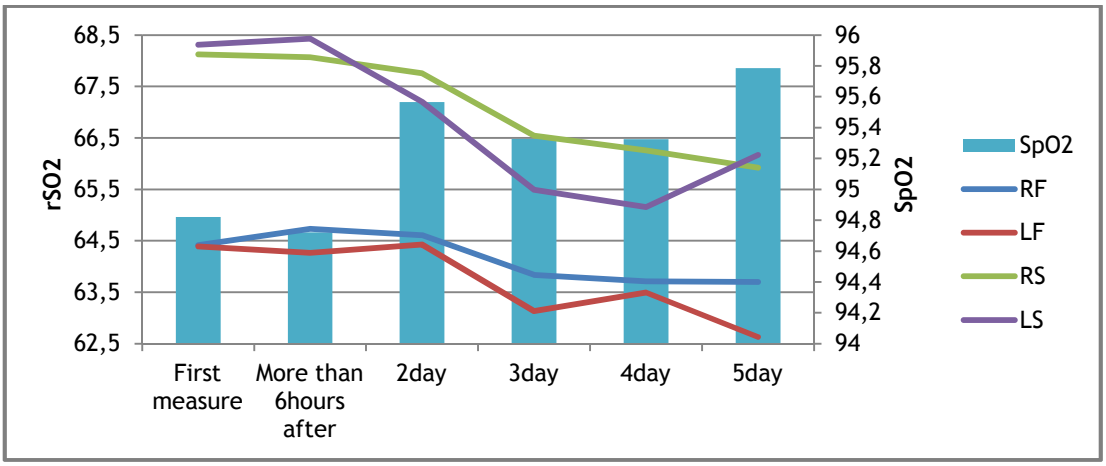

Figure 26. Graphic representation of the rSO^2 and SpO^2 measurements along the week.

Table 18. Statistical inference between rSO^2 values and SpO^2 values in the stroke unit population along the week.

		p-value: Chi-Square test			
		rSO^2 RF	LF	RS	LS
SpO^2 Vs rSO^2	First Measures	0	0	0	0
SpO^2 Vs rSO^2	After 6 hrs	0.056	0.03	0.02	0
SpO^2 Vs rSO^2	Second day	0.19	0.094	0.278	0.428
SpO^2 Vs rSO^2	Third Day	0.222	0.023	0.103	0.166
SpO^2 Vs rSO^2	Fourth Day	0.056	0.006	0.37	0.359
SpO^2 Vs rSO^2	Fifth Day	0.006	0.005	0.041	0.168

By analyzing figure 26 we can observe that SpO^2 levels rise along the week contrary to rSO^2 measurements that decrease. Nevertheless by observing table 17 we can see that SpO^2 and rSO^2 values often correlate.

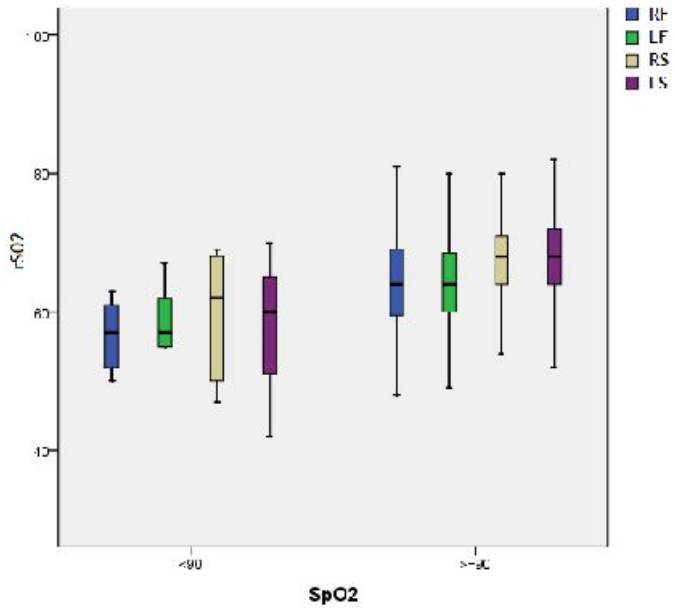

Figure 27. Graphic representation of the rSO^2 levels in the stroke unit individuals with SpO^2 values higher and lower than 90% .

Table 19. Statistical inference between the rSO^2 levels in the stroke unit individuals with SpO^2 values higher and lower than 90%.

	p-values: Mann-Whitney U			
	rSO^2 levels in those with >90 SpO^2			
rSO^2 levels in those with SpO^2 <90 mm/Hg	**RF**	**LF**	**RS**	**LS**
	0.009	**0.028**	**0.01**	**0.003**

We wanted to know if systemic oxygen levels drops detected on pulse oxymeters would also be detected by NIRS measurements. On figure 27 we can see that those who had higher values of SpO^2 also had higher levels of rSO^2, this has a statistically significant difference as shown in table 18. It seems as if NIRS measurements can detect systemic hypoxic events as well as those detected on pulse oxymeters.

Discussion

Few studies have been done about the utility of NIRS In the management of stroke, and no research study to date had a sample greater than two dozen individuals. The average age of our patients, similar to other studies(18, 19), was 75 years .The percentage of affected individuals by risk factors was also similar to the prevalence of other studies(20); hypertension affected 69%, DM , dyslipidemia and atrial fibrilation affected about one fifth of the popullation (figure7). Both genders were simmiliarly affected (figure 5).

One objective of our study was to find which factors influence rSO^2 values. By observing figure 19 It appears as if aging contributes to lower rSO^2 outputs but the results of table 2 indicate no diference with age increments. A larger study with a more diversified age sample should be done to exclude age as an influential factor in rSO^2 readings. Gender, as with age, seems not to affect rSO^2 values (Table 4). By observing table 5 it seems that no risk factor besides congestive heart failure had any influence on rSO^2 levels. Althought heart failure only presented two statiscaly significant differences, it seems that those afflicted with this pathology have lower rSO^2 values(figure 20 and 21). This had already been documented nearly twenty years ago using NIRS to detect vastus lateralis muscle hypoperfusion in those with heart failure(21). More studies should be undertaken in healthy individuals for one to be completely sure that these risk factors are independent of rSO^2 levels and to determine if heart failure can really be detected using cerebral NIRS measurements.

The main objective of our study was to discover the possible applications of Near Infrared Spectroscopy with its latest technological developments in a stroke unit. The predominant thinking was that by using a cerebral oximeter on acute stroke patients, we would measure low rSO^2 values; but after five months of collecting and analysing data we discovered, as seen on figure 22, that contrary to our innitial thoughts, a stroke patient in the acute setting has in fact higher oxigen values than a normal healthy individual. On figure 22 we can also see that these higher values decrease along the week towards the values of the heathy control group. These weekly variations in rSO^2 readings are proven statistically significant in table 11. Althought the difference of the rSO^2 values from the first measurements taken from stroke patients and the control group is small (≈4 points diference), this was also met with a statistically significant difference as shown on table 12, but only in the suprauricular sensors.

Innitially we thought that one possible cause that could explain this rSO^2 variation was the blood pressure, because as we know most patients that have a stroke have high blood pressure at admission. Even those who never had hypertension disease before, in the acute setting present thenselves with high blood pressure readings(20). Another point leading us to think that high blood pressure values influence SO^2 is the contorversy behind the initial

treatment of hypertension in an acute stroke patient where most studies(22) show that high blood pressure values exert protective effects preventing further brain necrosis due to better oxygenation. On figure 24 we can see the blood pressure variation during the week, as well as the rSO^2 levels along the week. As described in the literature,we have higher blood pressure values at the beginning that decline throughout the hospitalization. On table 16, we found out that there was no correlation between rSO^2 values and blood pressure measurements, suggesting other causes for the higher rSO^2 levels in the acute phase of a stroke. On figure 25 we were trying to see if low levels of blood pressure would influence rSO^2 measurements, but as shown in figure 25 and table 17 , again, no association was found between rSO^2 and low blood pressure values.

Studies such as "Focal cerebral hyperemia in acute stroke. Incidence, pathophysiology and clinical significance"(3) state that Hyperemia is the vascular response to a ischemic event that leads to high oxigenation values and therefore high rSO^2 is present in all stroke occurrences. Thus, we think that hyperemia is the reason why our measuers were higher in the beginning and declined along the week as hyperemia faded (figure 20). Although tables 13 and 14, show the lack of clinical statiscal relevance, by observing figure 21 and 22 it seems that the cerebral hemispheres with stroke lesions have higher rSO^2 values on the same side than in the healthy contra lateral side; therefore supporting the claim that a stroke produces a hyperemic region wrapped around the ischemical lesion. Hyperemia may influence NIRS measurements by increasing the vicarious circulation and therefore increasing the amount of cerebral oxygenated blood in stroke individuals. Hyperemia may also act on vasoconstrition, especially venoconstrition, diminishing deoxyhemoglobin with resulting higher NIRS readings since NIRS values reflect both oxyhemoglobin and deoxyhemoglobin.

A Previous pilot study done by Aries MJ et al(23) took NIRS measurements overnight concluding that the affected stroke hemisphere was more prone to dessaturations than the contralateral healthy side. We cannot conclude the same, since we only took instant readings and compared them with healthy individuals, not being able to identify when a systemic oxygenation drop occured;

Another objective of our study was to assess if NIRS is a viable means of diagnosing acute stroke individuals. Since we considered as a reference value 60 rSO^2, as proposed by David et al(9), by observing table 1, and comparing the low NIRS sensitivity(54%) and specificity(74%) with the 89% sensitivity and 100% specificity of a CT scan; we can say that NIRS is neither a good diagnostic tool, nor a good screening tool. The provable reason why NIRS has low sensitivity and specificity is because rSO^2 values are higher in stroke individuals, (as previusly show in figure 22 and commented above) so using values bellow 60 rSO^2 as reference is not correct for diagnosing stroke individuals. Nevertheless persons that present values bellow 60 rSO^2 are in a hipoxic state and medical intervencion is warranted, but a

stroke is not the probable underlying cause. To emphasize how NIRS failed in diagnosing stroke individuals we should take a look at figures 17 and 18 where we can see a higher percentage of individuals that have lower levels of rSO^2 in the control group (42%) than in the stroke unit (35%). More studies like the one made by Kirkpatrick PJ et al "Defining thresholds for critical ischemia by using near-infrared spectroscopy in the adult brain"(24) should be performed so we may have adjusted refference values for stroke individuals.

By observing the daily fluctuations of rSO^2 measurements in figure 16 we again see that different topographic regions of the brain present different rSO^2 levels, reflecting different local metabolic rates and different local cerebral blood flows. These differences account for the variances encountered between the frontal and suprauricular sensors as also seen in figure 22. It seems as if the temporal lobe (supra auricular sensors) have higher rSO^2 readings than the pre frontal cortex (frontal sensors) most of the time; this does not happen during the first hours of the day when both frontal and suprauricular sensors have almost the same readings (figure 16). We can explain the difference of night to day variations of rSO^2 readings by the different activities of the brain during those times.

When we were recovering data and taking measurements, both professionals that were in charge of taking NIRS readings reported the lowest values in individuals with Leukoariosis and with difuse billateral stenosis. They have been proved wrong by table 7 where we can see that both pathologies did not have statistically different rSO^2 values between persons afflicted with these diseases and those not afflicted. But they might still be right since we have detected that some doctors do not report these pathogies and others do. Other studies should be done to address this issue.

On table 6 we can see that individuals who had undergone thrombolysis did not have different rSO^2 values from those who had not; but it should be noted that in the 5 months of data recovery, only 5% of the study population had undergone thrombolysis (figure 5). A larger study should be performed so we can assess it's influence on rSO^2 values.

The results depicted on table 8 contradict what was said by Luis Fabrizio et al (16), when he obtained corresponding values from NIRS measurements and TU results. Our study did not find any statistical significant difference between flow alterations on TU and rSO^2 readings. On table 8 we can also see that CU had no statistical significant difference between lesions detected on CU and rSO^2 values. The reason why figure 11 states that CU detects more individuals affected by vascular flow abnormalities than TU is because these last pathologies are more uncommun since they occur in the vasculature of the brain instead of occuring in the carotid arteries.

When observing table 9 we can see that the place of injury detected on each of the imagiological exams did not have any influence on the rSO^2 levels.

One way to evaluate the severity of a lesion and the necessity of future care(25) is by using scales based on the physical and mental loss capabilities of each patient after the acute event has taken place. By observing figure 7 and 8 we can see that in our stroke population the most common type is the less severe type of pathological stroke corresponding to the highest values on the glasgow scale and to the lowest in the NIH stroke scale. Both scales have not presented any statistically significant difference in the rSO^2 levels as observed on table 10.

NIRS still has a long way to go to be acepted as a diagnostic tool. It will probably first be used as a bedside monitor(26) rather than as a sreening/ diagnostic instrument. The actual difficulties that NIRS has in providing good usufull diagnostic measurements are due to the different values obtained from the different biological barriers. Although NONIN NIRS Equanox technology manufactors state that this equipment successfully neutralizes the Barriers of Skin, meninges and bone(10, 27), we have detected intrapatient variations of rSO^2 meausures due to each patients physiological buildup. Factors like melanin in skin, lipid prevalent tissue, bone density and cerebrospinal fluid are some of the confounding factors in NIRS values from one individual to another. Some attempts made to clarify these factors have proven dificult to establish(28, 29), and if we pay close attention to the Equanox manufactors article when they state that their sensors give clear readings through the different biological barriers (10), we note that they do not specify the number of persons that they tried their sensors on nor their caracteristics. More studies will have to be done so these confounding factors are out of the equation.

As a bedside monitor, NIRS has already been established by some studies (30, 31) , but in ours we found that its correlation to SpO^2 levels was not clear, as show in table 18. In figure 26 we can also see that SpO^2 levels increase along the week, opposed to the rSO^2 levels that decrease as we previously stated. The probable explanation of the lack of correlation between rSO^2 and SpO^2 readings, may be due to the different location where both oxymeters were taking measurements, therefore a good reason to use NIRS as a regional cerebral oxymeter where pulse oxymeter can't take readings.

We have also tried to find if systemic oxygenation drops detected on pulse oxymeter would also be detected by NIRS. We identified every event during the week where a patient presented a SpO^2 value bellow 90 and measured their rSO^2 levels. In figure 27 we can see that individuals with SpO^2 levels lower 90 had lower rSO^2 levels than those with higher than 90 SpO^2 levels. This statistically significant difference, as presented in table 19, tells us that NIRS, such as a pulse oxymeter is a good mean to detect systemic oxygenation drops.

In spite of these confounding factors and lack of clinical utility presented by our study, we think that with new technological advancements; NIRS may, in the near future ,be an important asset in medical practice.

Study Limitations

The use of few sensors for multiple patients, accounts for 1% of the measurements intervariability and therefore error(10).

Not having the same doctors performing the imagiological reports for all individuals makes it hard to analyse the results, especially for pathologies like leukoariosis and difuse bilateral stenosis. If one is really looking to determine if these pathologies influence NIRS measurements the imagiological reports must be unanimous with all professionals evaluating these diseases .

Although 128 patients were studied in comparison with other studies that had much lower numbers. We only had a small sample of patients that had undergone thrombolysis and that had a reported pathological exam on TU; therefore we concluded that both these factors had no influence on rSO^2 readings but it may also be due to the small number of cases.

In our study we had a very elderlly population with little age variations, for us to be completely sure that age does not affect rSO^2 measurements, a study should be done with a greater age variation.

Final Considerations

In response to works like ***"Can Cerebrovascular Reactivity Be Measured With Near-Infrared Spectroscopy?*** (28), the anwser is yes. A Hyperemic state as a fisiological body response to an acute ischemical stroke can porbably be measured by near infrared spectroscopy with high rSO^2 measurements.

To awnser our own objective ***"Can NIRS correctly diagnose stroke Individuals"?*** The awnser is no. NIRS only detects the hyperemic area enclosing the ictus site and therefore acute stroke patients that only have a ≈4 points difference higher in their rSO^2 values than healthy individuals. This difference is too small for a diagnosis to be made.

Can NIRS Be used as a bedside monitor to assess systemic oxygenation drops and change the therapeutical course? Yes. NIRS has shown a good association between rSO^2 and SpO^2 values in those who presented with systemic oxygenation drops, but no terapeutical action was taken in response to NIRS measurements.

Can NIRS detect any of the studied CVA risk factors ? In our study NIRS has only shown a small association with heart failure, not showing any association with any other CVA risk factors. Therefore NIRS cannot be used in clinical practice for screanning any of the studied CVA risk factors.

Future Prospects

To further understand how hyperemia affects stroke patients, more studies must be undertaken to assess the factors that are contributing to the increase or decline in vascular response and their implication in clinical practice;and to be completely sure that NIRS can detect hyperemia, studies with the use of functional brain images should be performed so we can once and for all associate the two of them.

NIRS has a bright future ahead, it's feasibility, as a soon to become bedside monitor, is almost established; but as a diagnostic tool improvements have to be made. Specifically speaking, if NIRS is going to be used as a diagnostic tool in stroke individuals; hyperemic values should be taken into account. Once a way is established to detect these specific events, NIRS will probably in the future surpass CT scan as an inocual, inexpensive diagnostic tool.

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Attachments

Nota Informativa

"Viabilidade de NIRS em pacientes com Acidente Vascular Cerebral"

Estudo de Investigação prospectivo

Autor - Daniel André Gonçalves Torres

Orientador - Dr. Miguel Castelo Branco

Breve resumo - *Near Infrared Spectroscopy* (NIRS) é uma forma não invasiva de medir em tempo real a perfusão cerebral. Devido ao seu rápido e recente desenvolvimento existem ainda poucos dados concretos acerca das suas áreas de aplicação. O Acidente Vascular Cerebral (AVC) é um evento de início súbito, de origem isquémica ou hemorrágica, que pode evoluir para rápida perda de funções neurológicas, deixando graves sequelas ou mesmo causando a morte do paciente. O actual diagnóstico de pacientes com AVC é clínico, sendo o diagnóstico definitivo imagiológico (TC/RM).

Objectivos do estudo:

1) Determinar se, utilizando a tecnologia NIRS, é possível detectar valores de hipóxia num hemisfério cerebral responsáveis pela clínica do AVC, comparativamente com o hemisfério saudável;

2) Determinar se durante o seguimento de pacientes com AVC agudo a utilização de NIRS contribui para a modificação da terapêutica;

3) Comparar o rSO^2 cerebral obtido através da tecnologia NIRS e a SpO^2 periférica obtida com um oxímetro de pulso;

4) Medir os valores de "area under the curve" (AUC), utilizando uma baseline de 60 rSO^2, pois valores abaixo deste estão associados a mau prognóstico;

5) Investigar a possibilidade de aplicação da tecnologia NIRS como nova forma de diagnóstico e seguimento de pacientes com AVC agudo em unidades de cuidados intensivos (UCI).

Método de estudo - Consiste em utilizar a tecnologia NIRS (EQUANOX®) sobre todos os pacientes que apresentem AVC agudo isquémico na UCI do Centro Hospitalar Cova da Beira após estabilização e diagnóstico, colocando os sensores sobre o couro cabeludo em ambos os hemisférios cerebrais (necessária tricotomia na área do sensor).
Todos os pacientes terão de estar ligados a um oxímetro de pulso, sendo os resultados registados todas as horas, juntamente com os resultados do NIRS.

Será necessário para o estudo recolher a seguinte informação do paciente: Idade;
Sexo;

Hábitos tabágicos;

Antecedentes pessoais;

Saturações de O_2 periféricas (SpO^2; saturações de rSO^2 do aparelho EQUANOX da Nonim);

Resultados imagiológicos;

Confidencialidade e divulgação de resultados - Os dados deste trabalho serão tratados com confidencialidade assegurando os investigadores o cumprimento das normas vigentes. Os resultados deste trabalho serão potencialmente publicados, nunca antes do seu conhecimento pelo Centro Hospitalar da Cova da Beira, e seguindo as regras de privacidade e confidencialidade.

Consentimento Livre e Informado

Daniel André Gonçalves Torres, estudante de Medicina da Universidade da Beira Interior, a realizar um trabalho de investigação para aquisição de título de Mestre, subordinado ao tema" Viabilidade de Near Infrared Spectroscopy em pacientes com Acidente Vascular Cerebral.", vem solicitar a sua colaboração na realização deste estudo. Informo que a sua participação é voluntária, podendo desistir a qualquer momento sem que por isso venha a ser prejudicado nos cuidados de saúde prestados pelo CHCB, EPE; informo ainda que todos os dados recolhidos serão confidenciais.

Consentimento Informado

Ao assinar esta página está a confirmar o seguinte:

- Entregou esta informação
- Explicou o propósito deste trabalho
- Explicou e respondeu a todas as questões e dúvidas apresentadas pelo doente.

Daniel André Gonçalves Torres

Nome do Investigador (Legível)

_____ _____

(Assinatura do Investigador) **(Data)**

Consentimento Informado

Ao assinar esta página está a confirmar o seguinte:

- O Sr. (a) leu e compreendeu todas as informações desta informação, e teve tempo para as ponderar;
- Todas as suas questões foram respondidas satisfatoriamente;
- Se não percebeu qualquer das palavras, solicitou ao investigador que lhe fosse explicado, tendo este explicado todas as dúvidas;
- O Sr. (a) recebeu uma cópia desta informação, para a manter consigo.

_____ _____

Nome do Doente (Legível) **Representante Legal**

_____ _____

(Assinatura do Doente ou Representante Legal) **(Data)**