

## **Reliability of the Alberta stroke early CT scan (ASPECTS) and stroke classification in an emergency telestroke context**

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## **Aims and objectives**

To evaluate the use of mobile technologies that allow expert radiologists in acute stroke to diagnose this pathology remotely.

To determine and compare the clinical performance of observers using a conventional mobile device (IPAD) against the reference system (specialized medical monitor).

## Methods and materials

This retrospective study was approved by the ethics committee of our institution, and informed consent was not required. A factorial design with repeated measures was used in this study. The reliability refers to the reproducibility or agreement in measurements of the variables for each case rated by different observers (i.e., intradevice reliability), or rated by each observer using different treatments (i.e., interdevice reliability). The agreement assessment can be achieved using the kappa statistic.

### 1.1. Sample and standard:

Patients with symptoms of acute stroke, who attended emergency services for acute stroke evaluation between 2013 and 2016 at the Fundación Santa Fe de Bogotá University Hospital (FSFBUH), were included. Our hospital is a referral board certified stroke center. The age of patients ranged from 30-97 years, with a mean age of 71.6 years old (standard deviation of 15.1), 65 male and 72 female. The patients were randomly selected without repetition. Cases with images artifacts were excluded. The distribution of cases in the sample according to the type of lesions is shown in [Table 1](#) on page 7 .

The cases consisted of brain CT examinations stored in our hospital PACS. They were acquired using a General Electric LightSpeed 64 slice CT scanner (General Electric Healthcare, GE Medical Systems, Milwaukee, WI, USA), with 100 kV, 10 mAs, axial:5 mm, sagittal: 3 mm, FOV: 26 cm, pixel spacing: 0.469, matrix: 512 x 512, pitch: 0.984:1, and signed 15-bit pixel depth.

### 2. Observers and reading observed variables:

Five neuroradiologists (three with more than ten years of experience) and one fellow neuroradiologist, were selected as the observers. They were asked to classify the type of the stroke lesion (i.e., hemorrhagic lesion, ischemic lesion, chronic lesion, or without acute lesion). Further, according to the selected lesion type, the radiologist classified other values, as contraindications to the tPA administration for acute ischemic lesions, the confidence on the presence of the hyperdense intracranial artery (HIA), and the ASPECTS score (ranged from 1-10).

### 3. Display monitors and viewer software:

According to the American College of Radiology (ACR) guidelines for teleradiology, small matrix size images, such as CT, must be visualized on a monitor with a minimum of 512 x

512 matrix size at a minimum 8-bit pixel depth, for processing or manipulation with no loss of matrix size or bit depth at display. In addition, the Digital Imaging and Communications in Medicine (DICOM) standard recommends the use of monitors calibrated to a maximum luminance of 400-500 cd/m<sup>2</sup>. Therefore, we used two display with these specifications.

The routine system for CT readings in our hospital is to use a PACS workstation with a DICOM-compliant viewer software Agfa IMPAX 6.5 (AGFA HealthCare, Mortsel, Belgium). Images are displayed using an E-2620 BARCO monitor (BARCO N.V, Kortrijk, Belgium), which is a 2-megapixel (MPx) LCD medical grayscale display, DICOM-compliant, dot pitch of 0.249 mm, a spatial resolution of 1600 x 1200 pixels, a maximum luminance of 700 cd/ m<sup>2</sup>, and a 8-bit grayscale. This system, hereafter referred to as MEDICAL-IMPAX, was used as the reference reading system in this study.

For the mobile option, an Apple iPad Pro 9.7 MLMN2CL/A (Apple Inc., Cupertino, CA, USA), with a "retina" display of 9.7 inches, dot pitch of 0.096 mm (264 dpi), a spatial resolution of 1536 x 2048 pixels, and a maximum luminance of 500 cd/m<sup>2</sup> was selected. The viewer software used on this tablet was the Agfa XERO Viewer 3.0 (Agfa HealthCare, Mortsel, Belgium) software, hereafter referred to as TABLET-XERO.

#### **4. Data Analysis:**

Patients with ASPECTS score less than seven are not eligible to receive the tPA treatment. Therefore, we dichotomized the ASPECTS score into two categories as follows: 0 if the score was ranged from 1-6 (which is an indicator to not administrating the tPA treatment), and 1 if the score was ranged from 7-10 (which is an indicator of eligibility to administrate the tPA treatment).

We evaluated all agreements using: 1. the type of the stroke lesions, and 2. the ASPECTS score dichotomized. For these two variables we evaluated intradevice agreements (i.e., agreements between radiologists when interpreting using a single reading system), and interdevice agreement (i.e., agreements for all radiologists when interpreting the same patient images using the two different systems, i.e., MEDICAL-IMPAX and TABLET-XERO).

As a result, we evaluated the following four variables: 1) intradevice agreement on lesion classification, 2) interdevice agreement on lesion classification, 3) intradevice agreement on dichotomized-ASPECTS classification, and 4) interdevice agreements on dichotomized-ASPECTS classification.

These for variables were evaluated with the kappa coefficient as a measure of agreement. The kappa coefficients were ranked as defined by Landis and Koch: "Perfect", 1; "Almost Perfect", (1-0.8]; "Substantial", (0.8-0.6]; "Moderate", (0.6-0.4];

"Fair", (0.4-0.2]; "Slight", (0.2-0]; and "Poor", < 0. For these calculations, the software STATA 13.0 (Stata Corp, College Station, TX, USA) was used. In addition, the reading software calculates the reading time of each interpretation to perform an equivalence analysis, for which the software IBM SPSS Statistics 19 (SPSS Inc., USA) was used.

## 5. Procedure:

Each radiologist read all cases using both, the MEDICAL-IMPAX and the TABLET-XERO systems. At each reading, the radiologist determined the variables mentioned in the section "Observers and reading observed variables". The two reading software provides image manipulation tools to adjust window/level, zoom, and multiplanar reformation presentation. These tools were available for all images and could be used at the observer's discretion to improve image quality. For each reading session, the radiologist verified the settings of the contrast and luminance of the display with the RP-133 pattern in a controlled illumination (ambient light of approximately 20 lux according to the American Association of Physicists in Medicine (AAPM) TG18 recommendations).

The radiologist were blinded to the patient and examination identification, to the original interpretation, and to the type of lesion. To ensure that the radiologist were blinded, a junior radiology resident was charged to get the images into the PACS workstation or tablet using the IMPAX or XERO viewer software. The data collection was performed using a web-based form and interpretations were stored in a database. This software presents the patients to be interpreted at random, and guide the radiologists to complete the report, assuring integrity and completeness of data.

According to Mullins et al., the availability of a clinical history indicating that early stroke is suspected significantly improves the sensitivity for detecting strokes on unenhanced brain CT; whenever possible, relevant clinical history should be made available to physicians interpreting emergency CT scans of the head. Therefore, clinical history used in the standard protocol to interpret brain CT with suspicion of acute stroke, were available to radiologists, e.g., sex, age, principal symptoms, neurological concept, and relevant conditions (e.g., diabetes, hypertension, headache, Parkinson, Alzheimer, sleep apnea/hypopnea syndrome, or cardiac arrhythmia). This was made to achieve a more realistic interpretation. Hence, the only difference with the real practice was the display system. This information was presented in the web-based collection form before to begin each interpretation.

There were 121 different patients and five months before to repeat a patient for any radiologist. The readings were performed over the course of ten months in two- or four-hour sessions by each radiologist, with no time limitations for each reading. Initial display

was using the default image window setting (WW=174 and WL=55), but radiologists were free to select another window, as a cerebral or a stroke window (WW=80 and WL=40, WW=40 and WL=40, respectively).

Images for this section:



## Sample and standard

- Distribution of cases in the sample according to the type of lesions

ACV Type	Cases
Without Acute Lesion	7
Hemorrhagic lesion	13
Ischemic lesion	67
Chronic lesion	34
Total	121

**Table 1**

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# Results

## 1. Agreements on the lesion classification:

Intradvice agreements on the lesion classification observed in our study, for individual radiologist and for the overall group are presented in [Table 2](#) on page 11. Observed agreements were ranged from 63.6-82.6%, with kappa values ranged from 0.47-0.74, and agreements ranked as "Substantial" for two radiologists and "Moderate" for four radiologists ( $P < 0.001$ ). The overall radiologists observed agreement on lesion classification was 73.0%, with a value kappa of 0.6 and ranked as "Moderate" ( $P < 0.001$ ). These values were evaluated for each lesion type and result are shown in [Table 3](#) on page 11. All the observed agreements were ranged from 73.9-98.2%, with high kappa values, ranged from 0.50-0.89, and all ranked as "Moderate" or "Almost Perfect". The higher agreement was on hemorrhagic lesions, and the lower on chronic lesions. Nevertheless, when chronic and acute ischemic lesions were combined together into a category "Cerebral Infarction", high agreements were noted, with observed agreement of 81%, kappa of 0.6 and ranked as "Substantial". In the interpretation process, radiologists were asked to evaluate cases interpreted as ischemic lesions, for the presence or not of possible contraindications to receive the tPA treatment; for this variable named "Ischemic without contraindications", "Moderate" agreements were observed, with observed agreement of 75% and kappa of 0.43.

Intradvice agreement on the lesion classification by reading system, for individual lesions types and for the overall classification are presented in [Table 4](#) on page 12. The higher intradvice agreements were observed for hemorrhagic lesions; agreements were ranked as "Almost Perfect" in both Medical-IMPAX and TABLET-XERO reading systems, with kappa values of 0.90 and 0.82, respectively. The lower intradvice agreement was observed for chronic lesion using the Medical-IMPAX, with a kappa of 0.37, ranked as "Fair" agreement. Nevertheless, the rest of agreements were ranked as "Moderate" for both reading systems. For classification of "Cerebral Infarction" (acute or chronic), observed agreements were ranked as "Moderate" in both reading systems, with kappa values of 0.58.

## 2. Agreements on the ASPECTS classification:

The observed interdevice agreement on the dichotomized-ASPECTS classification (1-6;7-10), for the overall group of radiologists ([Table 5](#) on page 13) was ranked as "Substantial", with a kappa value of 0.65, and a high-observed agreement of 92.3%. For grouped ASPECTS categories (i.e., 1-3, 4-7, 8-9, and 10), the observed agreements were ranged from 80.7-98.6%, and kappa values were ranged from 0.43-0.66;



with "Substantial" agreements for ASPECTS 1-3 and ASPECTS 10 categories, and "Moderate" agreements for ASPECTS 4-7 and ASPECTS 8-9 categories.

### **3. Reading time:**

The reading time for interpretations on the Medical-IMPAX and Tablet-XERO were 126 s and 123 s, respectively, with no statistical significant difference ( $P = 0.566$ ). The difference time to claim equivalence was 13.7 s ( $P < 0.05$ ).

### **4. Discussion:**

High interdevice agreement on the lesion classification (i.e., agreement for radiologist when reading the same case with Medical-IMPAX and Tablet-XERO systems) were observed, all ranked as "Moderate" or "Substantial". Intradvice agreement on the lesion classification by reading system were all ranked as "Moderate" agreement for the combined classification, for both Medical-IMPAX and Tablet-XERO systems. For individual lesion type agreements (i.e., hemorrhagic lesion, ischemic lesion, chronic lesion, and without acute lesion) the marginal kappa values, in general, were lower than those for the combined classification were. This is a well-described effect by Feinstein and Cicchetti when variables are separated in individual categories.

Although the marginal kappa values were low for chronic lesion, very high agreements were noted on hemorrhagic lesion (ranked as "Almost Perfect" or "Substantial"). These results on hemorrhagic lesion in our study were as well in line with the results of some other studies where high agreements and accuracy were found for hemorrhagic lesions.


Low agreements, ranked as "Fair", were noted for chronic lesions on Medical-IMPAX. This effect may be due to a limitation of our study, as initially, for patients with multiple findings, as acute or chronic events, radiologists doubt to select a lesion type. For readings with the TABLET-XERO system, it was defined to classify these patients as acute (instead of chronic), which increased their agreements with respect to the Medical-IMPAX system that was the first used.

Very high agreements were noted on interdevice agreement on the dichotomized-ASPECTS classification (i.e., agreement for radiologist when reading the same case with Medical-IMPAX and Tablet-XERO systems), with agreements ranked as "Almost Perfect" or "Substantial" for individual radiologist or for the overall group. This is a relevant fact suggesting that the Medical-IMPAX and Tablet-XERO systems may be interchangeable, without loss in reliability.

Intradvice agreement on the dichotomized-ASPECTS classification were all ranked as "Moderate" agreement, regardless of the reading system.

One limitation of this study is that only cases classified as ischemic lesion, with no contraindications to receive the tPA treatment, were evaluated for the confidence of the presence of HIA. Therefore, the number of cases with scores assigned by the six radiologists on the two reading systems (i.e., 12 scores assigned by case), was every low to achieve a good analysis of this variable. Another limitation of our study is due to the illumination conditions. Readings using the Medical-IMPAX system were performed in a diagnostic reading stations with ambient lighting levels controlled according to the AAPM TG18 recommendations (i.e., 15-60 lux), in contrast, readings using the TABLET-XERO system were performed without controlling ambient lighting levels. Nevertheless, this situation is more realistic for a telestroke system in which a radiologists is asked to read the CT examination as soon as possible wherever he is.

Images for this section:

Departamento de  
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# Results

Intra-observer/Interdevice agreement on the lesion classification by radiologist (readings from Medical-IMPAX and Tablet-XERO).

Radiologist	Observed Agreement	Kappa*	Agreement†
NR 1	82.6%	0.74	Substantial
NR 2	70.3%	0.55	Moderate
NR 3	64.5%	0.50	Moderate
NR 4	82.6%	0.74	Substantial
NR 5	63.6%	0.47	Moderate
FNR	74.4%	0.60	Moderate
Overall	73%	0.60	Moderate

NR: neuroradiologist; FNR: fellow neuroradiologist. All values significant ( $P < 0.001$ ).  
\* Each radiologist agreement was calculated from 242 readings (121 cases by 2 reading systems).  
† As defined by Landis and Koch.

**Table 2**

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# Results

Intra-observer/Interdevice agreement on analyzed variables for overall radiologists (readings from Medical-IMPAX and Tablet-XERO).

Variable	Observed Agreement	Kappa	Agreement
<b>Lesion classification</b>			
Overall categories	73%	0.60	Moderate
Without acute lesion	81%	0.56	Moderate
Hemorrhagic lesion	98%	0.89	Almost Perfect
Ischemic lesion	79%	0.58	Moderate
Chronic lesion	87%	0.50	Moderate
Cerebral Infarction	81%	0.60	Substantial

**Table 3**

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# Results

Intra-observer agreement on the lesion classification by reading system.

Lesion type	Reading system	Kappa	Agreement
Overall categories	Medical IMPAX	0.54	Moderate
	Tablet Xero	0.52	Moderate
Without acute lesion	Medical IMPAX	0.53	Moderate
	Tablet Xero	0.48	Moderate
Hemorrhagic lesion	Medical IMPAX	0.90	Almost Perfect
	Tablet Xero	0.82	Almost Perfect
Ischemic lesion	Medical IMPAX	0.50	Moderate
	Tablet Xero	0.51	Moderate
Chronic lesion	Medical IMPAX	0.37	Fair
	Tablet Xero	0.40	Moderate
Cerebral Infarction	Medical IMPAX	0.58	Moderate
	Tablet Xero	0.58	Moderate

**Table 4**

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# Results

The observed interdevice agreement on the dichotomized-ASPECTS classification, for the overall group of radiologists

Variable	Observed Agreement	Kappa	Agreement
Dichotomized-ASPECTS (1-3; 7-10)	92.3%	0.65	Substantial

**Table 5**

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## Conclusion

High observed-agreements, high observed concordances for interrater and intrarater agreements on the variables evaluated (with respect of other studies on brain CT), and agreements ranged from moderate to almost perfect, were observed in this study. Such results allow us to suggest that in the telestroke context of our hospital, and performing interpretation as close and realistic as they are in routine interpretation in our hospital, the reliability of the evaluated mobile solution for interpreting brain CT of patients with signs of acute stroke was assured. Reading time difference was not a concern in this study. In our study, reading using the tablet were performed over a Wi-Fi connection; for a more realistic approaches in our country, where public Wi-Fi is not available, an evaluation of time transfers over mobile telephone networks, as the 4G, and their costs, is necessary.

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