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The use of teleradiology for triaging of maxillofacial trauma

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ABSTRACT

Purpose: The aim of this study was to assess and discuss our experience with a teleradiology technique applied to facial trauma patients referred to an oral and maxillofacial surgery hub center.
Materials and methods: All trauma patients with maxillofacial fractures from the hospitals of Vercelli, Biella, Borgosesia, Borgomanero, Verbania, and Domodossola who were referred between July 2014 and September 2018 to the hub maxillofacial center of Novara were reviewed. The following data were recorded for each patient: sex, age, referral hospital, etiology, etiology mechanisms, site of facial fractures, date of injury, indications for surgery according to teleradiology consultation, indications for surgery following clinical maxillofacial assessment, date of eventual surgery, timing of surgery from trauma, type of surgical intervention.
Results: A total of 467 patients with a total of 605 fractures were triaged and managed by the Tempore telemedicine system. The most frequent cause of maxillofacial injury was fall. The most frequently observed fracture involved the zygoma. Following remote computed tomography assessment, surgical indications were suggested in 68 patients; 223 patients were not considered suitable candidates for surgery; and 176 patients needed a clinical assessment for the establishment of definitive eventual indications for surgery. Following clinical assessment, the absence and presence of surgical indications was confirmed in all 223 and 68 patients, respectively. Within the 176 patients with "possible" surgical indications, only 27 patients were referred for surgery.
Conclusion: Teleradiology may be helpful for an appropriate triaging of trauma patients from peripheral hospitals for the correct referral to a maxillofacial trauma hub center.

1. Introduction

Maxillofacial injuries are a serious public health and economic problem, as their diagnosis, management, and time spent in hospital and out of work is expensive. These injuries are also often associated with severe morbidity, disfigurement, and psychological/social problems. Furthermore, the epidemiology of maxillofacial fractures is extremely variable, depending on several factors such as the geographical area, cultural and lifestyle differences, and socioeconomic trends (Ambroise et al., 2018; Aziz and Ziccardi, 2009; Brockes et al., 2012; Brownrigg et al., 2004; Yang et al., 2016; Ewers et al., 2005; Farook et al., 2013; Gardiner and Hartzell, 2012; Hutchison and Morrison, 2012; Rollert et al., 1999; Wood et al., 2016a, 2016b; Brucoli et al., 2018a, 2018b; Kommers et al., 2015; Bins et al., 2015; Boffano et al., 2014; Salentijn et al., 2014; Giarda et al., 2015; Arcuri et al., 2012). Therefore, it may prove challenging to create an ideal clinical pathway for the diagnosis and management of facial trauma that could be applicable all around the world, considering also the profound differences of national health systems.

As maxillofacial trauma, in comparison for example with orthopedic trauma, has a quite low incidence, it may be extremely difficult to plan an appropriate and rapid maxillofacial assessment in specific uncomfortable scenarios, such as broad and desert/countryside regions, or underpopulated mountain areas. In such conditions, the diagnosis of a maxillofacial trauma and the consequent management could represent a challenge, especially if the nearest maxillofacial surgeon or hospital division of maxillofacial surgery is far away from the trauma site.

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To this aim, the concept of telemedicine may prove to be helpful to solve the aforementioned problems associated with geographic distance as well as to improve the quality of medical care and the appropriate triaging of patients, especially in regions and areas where access is limited for geographic, social, or healthcare reasons.

Telemedicine is a form of remote medical practice using information and communication technologies combined with medical information technology to provide remote medical services. It connects one or more health professionals either with other health professionals or with patients (Ambroise et al., 2018; Aziz and Ziccardi, 2009; Brockes et al., 2012; Brownrigg et al., 2004; Yang et al., 2016).

In particular, teleradiology may be helpful for an appropriate triaging of trauma patients from local ("spoke") hospitals for the correct referral to a "hub" maxillofacial trauma center.

The Novara University Hospital is the largest hospital within the National Health System of the northeastern area of the Piedmont region, Italy. It is a teaching hospital and has around 710 beds. It serves Novara, the second largest city in Piedmont, and it represents the "hub" maxillofacial trauma center for the surrounding area, including the Provinces of Novara, Vercelli, Biella and Verbano-Cusio-Ossola and in particular the hospitals of Vercelli, Biella, Borgosesia, Borgomanero, Verbania, and Domodossola. In 2018, the population of this subregion included about 880,000 people, residing on a surface of 6590 square kilometres, 2% of Italy's overall territory.

The teleradiology technology called "Tempore" has been operating since 2014, supporting the emergency departments of the six aforementioned local community hospitals for several injury types.

The aim of this study was to assess and discuss our experience with a teleradiology technique applied to facial trauma patients referred to an oral and maxillofacial surgery hub center.

2. Materials and methods

2.1. Teleradiology technique and referral pathway

As one of the regional hub centers for maxillofacial trauma surgery in the country, Novara University Hospital has had a teleradiology referral system (called Tempore) since 2014. This allows computed tomography (CT) scans of injured patients to be reviewed and to provide necessary advice and information to the referring unit.

Tempore is a store-and-forward telemedicine system. Once a trauma patient arrives in a "spoke" hospital, he or she is triaged and clinically and radiologically assessed by the local Emergency Department. Then, when the patient has a suspected or actual diagnosis of maxillofacial injury, the local medical practitioner from the spoke center contacts by phone the maxillofacial surgeon of the hub center, reporting past medical history, recent trauma history, as well as clinical examination findings of the patient. Finally, the spoke center transfers the CT examination findings as well as a short report of clinical history of the patient to the hub center via the Tempore system (which works thanks to a secure online consultation website with https transmission and password protection).

This store-and-forward system can be accessed at any computer terminal inside the Novara University Hospital via specific passwords. The hub maxillofacial surgeon evaluates the CT examination findings, together with the orally received information, and answers with a suggestion of "no indication for surgery," "possible indication for surgery," or "indication for surgery."

To sum up, "no indication for surgery" was assigned to patients who had undisplaced fractures or that suffered from serious medical conditions that would anyway prevent surgery in mildly dislocated fractures. "Indication for surgery" was assigned to patients who presented with displaced fractures, mandibular fractures or other fractures that would necessitates surgery in the opinion of the maxillofacial surgeon. "Possible indication for surgery" was assigned to doubtful cases or to most orbital wall fractures (in which clinical/ophthalmological assessment was considered to be crucial for the establishment of surgical indications).

In this first period of the learning curve, all patients with no indication for surgery were clinically re-assessed at the hub center when clinical conditions allowed for it and when further clinical issues were resolved, to check the appropriateness of the absence of surgical indications.

Patients with indication for surgery were immediately transferred from the spoke center to the hub center for clinical reassessment and surgery.

Finally, patients with possible indication for surgery were clinically reassessed at the hub center as soon as clinical general conditions allowed for it. Then, surgery or observation was advised.

As for the timeframe, the Emergency Departments of the peripheral "spoke" hospitals are 24-hour services. Initially, the patients were brought to the Emergency Departments of each peripheral hospital by emergency vehicles. After the admission to the peripheral hospital, trauma patients immediately were clinically and radiologically assessed by Emergency Department physicians. Then, maxillofacial surgeons were contacted on a regular basis whenever a facial fracture was diagnosed, at the end of the consultation by the physician of the emergency department (within about 2–3 hours after the admission to hospital). Then, CT examination findings were transferred to the hub center via the Tempore system, and patients with indication for surgery were immediately transferred from the spoke center to the hub center for clinical reassessment and surgery.

2.2. Methods

This study was based on a computer-assisted database that allowed the recording of all trauma patients with maxillofacial fractures from the hospitals of Vercelli, Biella, Borgosesia, Borgomanero, Verbania, and Domodossola who were referred to the Division of Maxillofacial Surgery of Novara University Hospital, University of Eastern Piedmont, Novara, Italy, from July 1 2014 to 30 September 2018.

The following data were recorded for each patient: sex, age, referral hospital, etiology, etiology mechanisms, site of facial fractures, Facial Injury Severity Score (FISS), date of injury, indications for surgery according to teleradiology consultation, indications for surgery following clinical maxillofacial assessment, date of eventual surgery, timing of surgery from trauma, and type of surgical intervention.

Etiology was classified as follows: fall, motor vehicle accident (MVA), assault, bicycle accident, work accident, sport accident, or other.

Etiology mechanisms subtypes were considered for falls (accidental, from ladder, following syncope/loss of consciousness/epilepsy, following alcohol abuse, from height >3 m), MVA (automobile, motorcycle, pedestrian hit by vehicle), and sport (football, horse riding, ski, basketball, other sport).

Fractures were classified in fractures of the mandible, orbitozygomatic-maxillary complex (OZM), orbit, nose, Le Fort, frontal sinus, and naso–orbital–ethmoidal (NOE) fracture. Orbital fractures were subclassified according to the involved walls, and Le Fort fractures were divided according to Le Fort types I, II, and III. Mandibular fractures included fractures of the symphysis, body,

angle, ramus, coronoid, extraarticular condyle, and intraarticular condyle.

FISS is an injury scale specific for facial trauma, which correlates with patient outcome and aims to provide a practical tool for communication between clinicians and healthcare personnel for management of facial trauma (Bagheri et al., 2006). The FISS score is considered to be easily calculated and to reliably predict the severity of maxillofacial injuries as measured by the OR charges required to treat the facial injury. In the literature, it can be used as a predictor of the predisposition for a longer hospital stay, the need for surgical procedures and the need for multiprofessional treatment by other specialties (Aita et al., 2018).

Indications for surgery according to teleradiology consultation and following clinical maxillofacial assessment were classified, as previously mentioned, as "indication for surgery", "no indication for surgery", or "possible indication for surgery".

Timing of surgery from trauma was calculated in days.

Type of surgical intervention was classified in closed treatment (e.g. closed reduction of zygomatic arch fracture, closed reduction of dentoalveolar fracture) and open reduction and internal fixation (ORIF).

Patient characteristics were analyzed using descriptive statistics.

This study was exempt from institutional review board approval as a retrospective review. We followed the Declaration of Helsinki guidelines. Informed consent was obtained from all patients.

3. Results

Between July 2014 and September 2018, a total of 467 maxillofacial trauma patients (285 male, 182 female) with a total of 605 fractures were triaged and managed by the Tempore telemedicine system within the Hub and Spoke hospital network. Mean age of the study population was 61,3 years (range, 10–102; median, 65; SD, 22,2).

Most patients were referred by Borgomanero hospital (157 patients), followed by Biella hospital (144 patients), and Borgosesia hospital (71 patients), as shown in Fig. 1.

The most frequent cause of maxillofacial injury was fall (260 cases), followed by MVAs (85 cases), assault (42 cases), and bicycle accidents (35 cases) (Fig. 2).

Within the fall subgroup, the most frequent etiological mechanism was accidental fall (154 patients); within MVA subgroup, the most frequently observed cause was automobile (66 patients); finally, among sport accidents, football was the most common cause of maxillofacial injury (15 patients) (Fig. 3).

The progressively increased use of the Tempore system within the northeastern part of the Piedmont region is shown in Fig. 4,

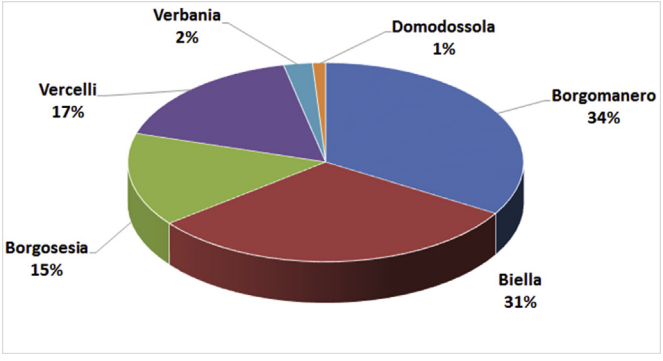

Fig. 1. Percentages of patients from the different peripheral referral hospitals.

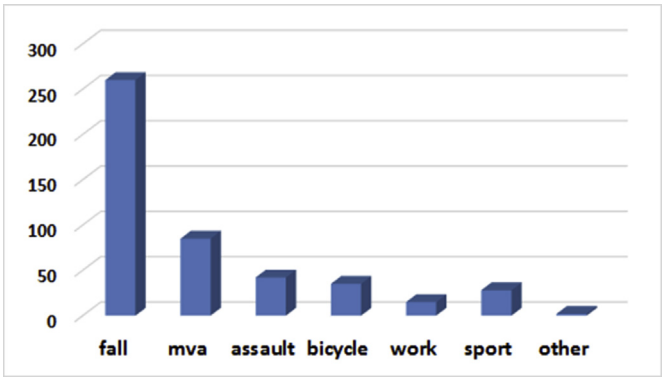

Fig. 2. Etiology of maxillofacial injuries.

which highlights that the number of teleradiology consultations increased from 7 (in the third quarter of 2014) to 43 (in the third quarter of 2018).

The most frequently observed fracture involved the orbitozygomatic- maxillary (OZM) complex, with 241 fractures, followed by pure orbital wall fractures (158), mandible fractures (74), maxillary sinus wall fractures (39), nose fractures (37 fractures), Le Fort fractures (30), frontal sinus fractures (14), NOE fractures (6), and dentoalveolar fractures (6) (Fig. 5).

FISS mean score in the whole study population was 1.55 (range, 1–12; median, 1; standard deviation, 1.17).

Fig. 6 shows the clinical pathway of the Tempore teleradiology system within our study population, summarized by an algorithm. In a first instance, following CT assessment by the maxillofacial surgeon from Novara University Hospital, surgical indications were suggested in 68 patients, whereas 223 patients were not considered suitable candidates for surgery, and 176 patients needed a clinical assessment for the establishment of definitive eventual indications for surgery.

Following clinical assessment, the absence of surgical indications was confirmed in all 223 patients who had already been considered not suitable candidates for surgery, and all 68 surgical indications were confirmed.

Of the 176 patients with "possible" surgical indications, only 27 patients were advised for surgery.

Fig. 7 shows the details of variation of surgical indications according to fractures between the first teleradiology assessment and the second clinical assessment.

On the whole, mean timing from trauma to surgery (when surgery was needed) was 4,3 days (range, 0–13; median, 4; standard deviation, 2,7). Of the 95 surgical cases, 86 underwent ORIF, whereas 9 underwent closed treatment.

4. Discussion

Telemedicine is gaining popularity in multiple medical and dental specialties because it improves access to care, it allows remote diagnosis, and it may reduce unnecessary transfers (Ambroise et al., 2018; Aziz and Ziccardi, 2009; Brockes et al., 2012; Brownrigg et al., 2004; Yang et al., 2016; Ewers et al., 2005; Farook et al., 2013; Gardiner and Hartzell, 2012; Hutchison and Morrison, 2012).

Of course, telemedicine can be used in a variety of situations. However, much work needs to be done to demonstrate that it has clear benefits over standard care, and it is important to be aware of how to use this technology safely and in a secure way (Ambroise et al., 2018; Aziz and Ziccardi, 2009; Brockes et al., 2012; Brownrigg et al., 2004; Yang et al., 2016; Ewers et al., 2005;

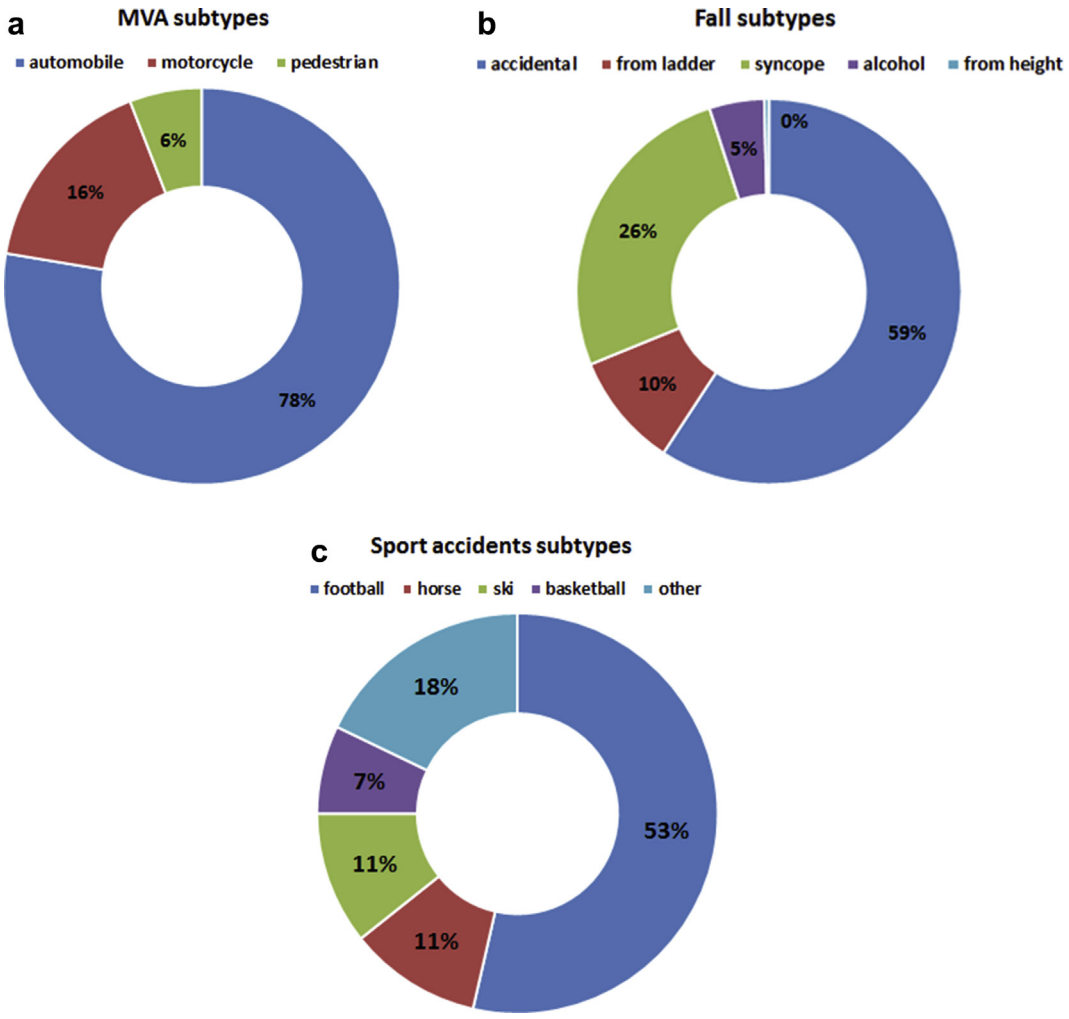

Fig. 3. Etiological mechanism subtypes of motor vehicle accidents (A), falls (B), and sport accidents (C).

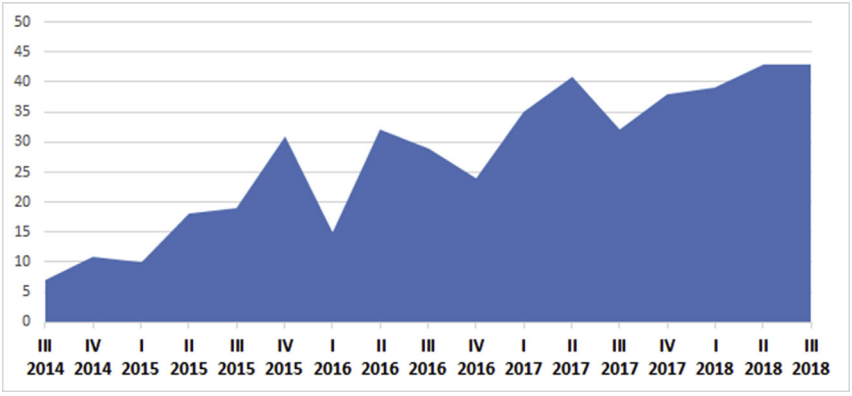

Fig. 4. Quarterly distribution of teleradiology between July 2014 and September 2018.

Farook et al., 2013; Gardiner and Hartzell, 2012). The ideal modality for medical image transfer is via a secure online consultation website (https transmission and password protection). (Ambroise et al., 2018; Aziz and Ziccardi, 2009; Brockes et al., 2012; Brownrigg et al., 2004; Yang et al., 2016; Ewers et al., 2005; Farook et al., 2013; Gardiner and Hartzell, 2012; Hutchison and Morrison, 2012; Rollert et al., 1999).

Maxillofacial trauma is a field that can take advantage of this technology to remotely review maxillofacial imaging, whether it be preoperative, postoperative, or emergent.

Our Tempore teleradiology system can be considered a "Store-and-forward (asynchronous)" system according to the American Dental Association (ADA)'s Comprehensive Policy Statement on Teledentistry. In fact, transmission of recorded health information

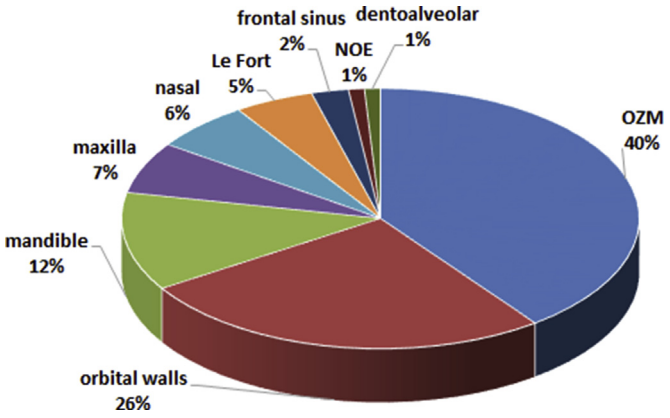

Fig. 5. Fracture distribution within the study population.

(in our case, radiographs) is performed through a secure electronic communications system from a peripheral spoke hospital to the hub maxillofacial center, which uses both the teleradiology information and that communicated orally by telephone full to obtain a clinical history to evaluate a patient's condition and to ensure the most appropriate clinical pathway for each maxillofacial trauma patient.

Telemedicine makes the first triaging consultation more accurate by allowing the specialist to review digital imaging outside the peripheral medical center (Ambroise et al., 2018; Aziz and Ziccardi, 2009; Brockes et al., 2012; Brownrigg et al., 2004; Yang et al., 2016; Ewers et al., 2005; Farook et al., 2013; Gardiner and Hartzell, 2012).

Our experience highlights that telemedicine is a useful tool to rationalize transfers from peripheral spoke centers to maxillofacial hub centers.

The analysis of the results of our experience with Tempore teleradiology system allows for several discussions.

First, a great appreciation of this teleradiology consultation service was reported by all peripheral hospitals, as it is confirmed by the progressive increase of the number of consultations in the last few years (Figs. 1 and 4).

Second, our study population can be used for a more precise analysis of the epidemiology of maxillofacial trauma. In fact, in the literature, most studies are focused on the epidemiology of maxillofacial trauma surgical patients, by the review of performed surgical interventions. Instead, our population would virtually

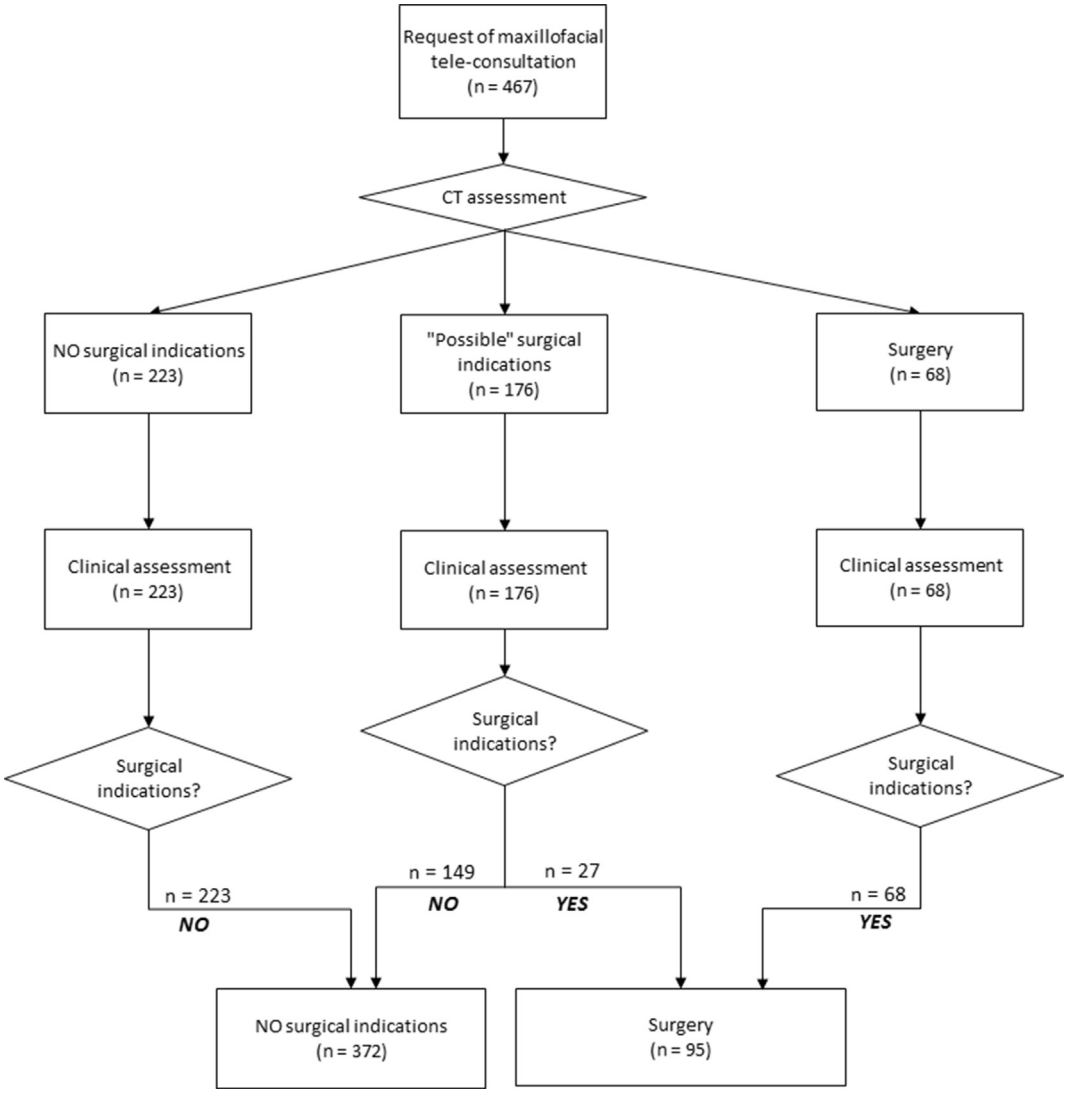

Fig. 6. Algorithm showing the clinical pathway of patients triaging by the Tempore teleradiology system.

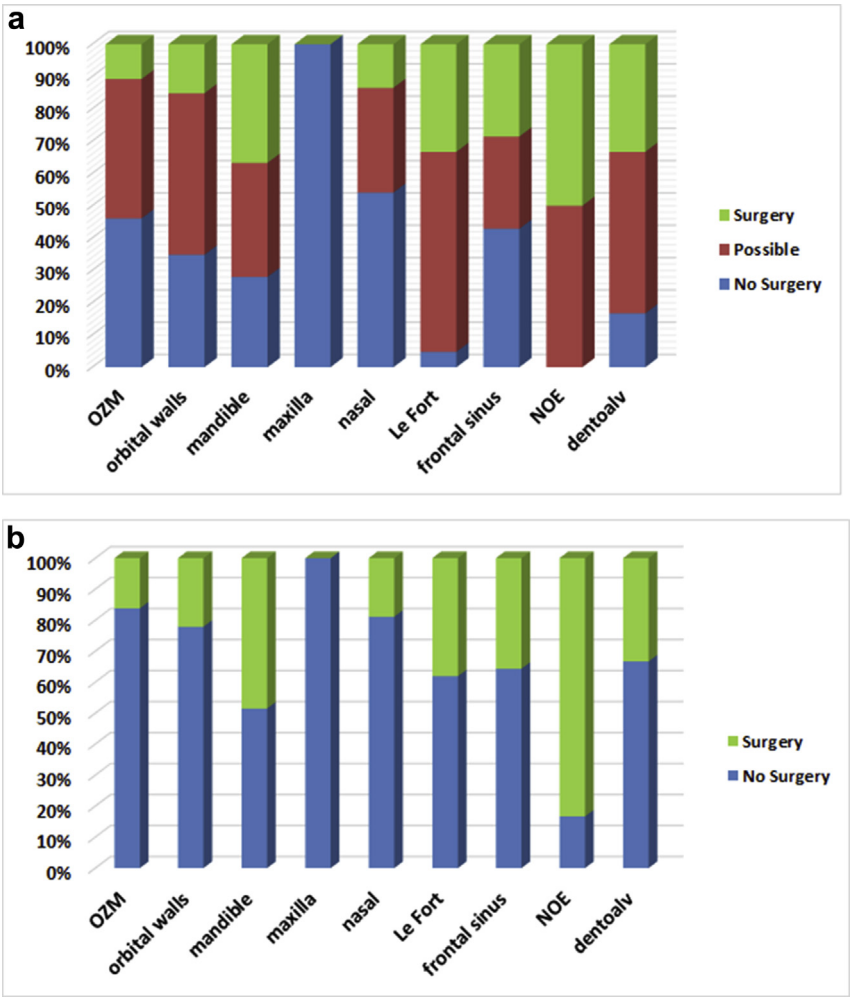

Fig. 7. Percentages of indications for surgery (yes, no, possible) following the first teleradiology consultations (A), and following the clinical re-assessment (B).

allow the assessment of both surgical and nonsurgical maxillofacial trauma. Falls were overwhelming as etiological factor, accounting for the 55,7% of patients. The great proportion of elderly patients confirms that the ageing of Occidental countries' populations represents an important issue for maxillofacial traumatology, as more and more patients become more than 65 years of age. To this aim, it is interesting to observe that OZM fractures together with orbital walls fractures accounted for more than 65% of all maxillofacial injuries. Therefore, with the obvious exception of nasal fractures, which has a bias risk due to the referral to otolaryngology divisions, mandibular fractures seem to have a quite low incidence in the general population.

Our clinical assessment in all patients, even in non-surgical patients, was aimed to check the appropriate and safe use of teleradiology as a sort of distance-triaging system. Therefore, the good results and success of our teleradiology–clinical pathway, as shown in Fig. 6, encourages us to continue to use the actual system and to trust it. A possible next step could be to limit the clinical re-assessment of patients without surgical indications after Tempore consultations to patients with specific health conditions.

Finally, the analysis of percentages of fractures with or without indications to surgery following clinical re-assessment (Fig. 7) shows that, with the exception of NOE fractures (which may suffer from bias due to the low number), all fractures maintain about the same percentages following the Tempore consultation and following the clinical assessment. This may be due to the need for clinical reassessment in most cases of elderly patients who suffer from cognitive decline, Alzheimer disease, or further serious illnesses that, in spite of the displacement of maxillofacial fractures, could limit surgical indications.

Therefore, Tempore teleradiology system has proved to be cost-effective, simple, and user-friendly. A very short learning curve was needed, according to both maxillofacial surgeons and peripheral center personnel. Face-to-face consultation by the maxillofacial surgeons did not highlight any discrepancies from the teleradiology consultations in surgical and non-surgical cases. The northeastern part of the Piedmont region is a broad hill and mountain area that perfectly suits a teleradiology system. In fact, the distance between the centers may affect a prompt and appropriate triaging of trauma conditions that need specialist consultation, such as maxillofacial surgical consultation. Our hub and spoke maxillofacial system allows for an appropriate maxillofacial trauma triaging of a population of about 880,000 people, residing in an area of about 6590 square kilometers.

Users were satisfied with the system. Of course, telemedicine referrals require new thinking in terms of patient administration, with more appropriate traditional referral logistics (Ambroise et al., 2018; Aziz and Ziccardi, 2009; Brockes et al., 2012; Brownrigg et al., 2004; Yang et al., 2016; Ewers et al., 2005; Farook et al., 2013; Gardiner and Hartzell, 2012; Hutchison and Morrison, 2012; Aita

et al., 2018; Brucoli et al., 2019a, 2019b, 2019c, 2019d). Urgent transfers may be avoided for patients who are more suitable for review in out-patient clinics.

5. Conclusions

In conclusion, teleradiology seems to facilitate the exchange of specialist skills with local colleagues, thus proving to be an efficient and effective way for achieving remote maxillofacial specialist consultation. An improved efficiency of the specialty consultation and improved triaging may be obtained in broad, rural and/or mountain regions, ultimately providing improved care to the maxillofacial patient. An important role in the early management of peripheral referrals of maxillofacial trauma cases, many of which do not require transfer, may be assigned to teleradiology systems. Nevertheless, telemedicine will not replace face-to-face consultation for most patients, who need to be seen in a maxillofacial surgery department. However, unnecessary transfers to hub centers could be reduced, as confirmed by our experience.

The use of telemedicine in maxillofacial trauma may be promoted within national health systems as, it proved to be simple and cost-effective.

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