Experimental study on positioning uncertainty of patients treated with stereotactic encephalic radiotherapy using surgical mask in Covid-19 era: analysis of dosimetric and set-up parameters

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KeyWords:
Radiotherapy, Placement error, surgical mask, Covid-19, brain injury, TSRM, stereotaxis, dose, infection control, risk management, patient safety, health worker safety

RESEARCH ARTICLE

Abstract

Aim

To evaluate the positioning uncertainty in patients treated with encephalic stereotactic technique using the combination of a surgical mask with thermoplastic mask for immobilization of radiotherapy treatment.

Materials and methods

Retrospective "Matched Pair" review and evaluation of a sample of 19 patients, divided into two groups, treated between November 2018 and March 2022 with a number of active lesions less than or equal to 2 on magnetic resonance imaging (MRI): the first group includes patients treated in the pre-Covid-19 era and immobilized without a surgical mask, while the second treated in the Covid-19 era with a surgical mask.

Results

The study showed that there were no statistically significant differences between the two study groups by obtaining as positioning error in Verticality (Y-axis) values of 0.5 mm without surgical mask compared with -0.4 mm with surgical mask; in Longitudinal (Z-axis) values of -0.3 mm compared with 0.2 mm with surgical mask and finally in Laterality (X-axis) values of -0.6 mm without surgical mask compared with 0.1 mm with surgical mask. Subsequently, dose fluence analysis also confirmed the set-up reliability datum with the online in vivo dosimetry reproducibility datum.

Discussion

The association of the surgical mask with the thermoplastic mask, which was necessary in the Covid-19 era, proved to be essential in order to ensure the quality of treatments delivered without compromising the safety of operators and patients within the Operating Unit.

INTRODUCTION

Worldwide, the epidemic caused by Covid-19 has imposed a very high level of alertness. The repercussions of this phenomenon have also been felt particularly in the field of Radiotherapy, where on the one hand the adequate continuity of care of radiotherapy treatments had to be guaranteed and on the other hand the protection of the health of oncology patients, who are already fragile and potentially more at risk of infection.

Based on Recommendations and Guidelines[1] issued as a matter of urgency, technical and nursing tasks were introduced without historical precendent.

In particular, there has been a need for a change in strategic vision for the management of potential pandemic containment especially for patients being treated with thermoplastic masks, as they usually lack personal protective systems during the radiotherapy session.

Many debates have centered on the concern of allowing such patients to wear face masks in radiation oncology clinics.

As a result of the pandemic development and the stringent emergency criticality, it was necessary to conduct a retrospective analysis on the possibility of new set-up errors and the uncertainty of positioning reproducibility in the light of observational

[1] *Guidance document for risk assessment and management of patients and operators in radiation oncology departments being disseminated by Covid-19 - Italian Association of Radiotherapy and Clinical Oncology*

Citation: F.Scommegna, A.Errico, M.Doronzo, L.Cannito, G.Guglielmi "Experimental study on positioning uncertainty of patients treated with stereotactic encephalic radiotherapy using surgical mask in Covid-19 era: analysis of dosimetric and set-up parameters" JAHC 5:4

Received: 03/10/2023
Revised: 12/10/2023
Accepted: 17/10/2023

scientific studies published only at the end of the year 2021.
On the basis of this, the experimental study conducted at the O.U. of Radiotherapy in Barletta stems from the same desire to aspire to a prospective evolution of clinical practices by moving from the experimental criticization of its own work in order to make exponential improvements in care.

MATERIALS AND METHODS

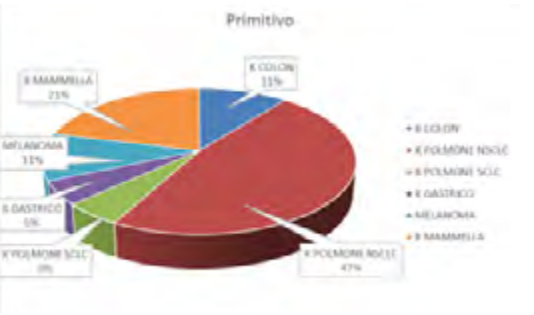
Nineteen patients, undergoing treatment between November 2018 and March 2022, who had a number of active lesions less than or equal to 2 on magnetic resonance imaging (MRI), done to complete the clinical picture, were included in the study.
A Matched Pair analysis was conducted focusing on the technical-diagnostic area of treatment and dividing the sample into two groups with overlapping clinical and dosimetric characteristics.
The first group includes patients treated in the pre-Covid-19 era immobilized using only the thermoplastic mask, while the second group includes patients treated in the Covid-19 era in whom the surgical mask was placed below the thermoplastic mask.
All were treated with SBRT (stereo body radiotherapy) of which 13 were treated with IMRT (intensity modulated radiation therapy) technique, 6 with VMAT (volumetric modulated arc therapy) technique and immobilized in simulation session with a 5prong thermoplastic mask, on which three marks (1 central + 2 latero-lateral) were marked with the addition of 1 sternal alignment mark.
There are two exceptions: a patient treated in June 2020 in the midst of the Covid-19 era, for whom a large 9-prong mask was used, and a patient treated in March 2022 who used the new Civco ® stereotactic helmet (Kalona, USA), a new immobilization system in the O.U. of Barletta.

Clinical characterization of the sample

The mean age of patients at study entry was 63 years (range 42-78) with a predominance of men over women. Only 3 patients, or 16% of the study sample underwent stereotactic treatment on the previously operated tumor bed, while the remainder were radio-treated on in situ metastatic brain lesions.
One can see from the 'histogram a prevalence of lesions in the right frontal site.

***Graphic 1**: site of active lesions*

The pie chart in the graphic 2, on the other hand, shows the different percentages regarding the



***Graphic 2**: Stratification of the starting primitive*

study's starting primitives.
As shown in the graph, the most frequent primary cancers are non-small-cell lung cancer (NSCLC), which accounts for 47 percent of the sample histotype and breast cancer, which accounts for 21 percent histotype.

Simulation and planning imaging

For treatment planning, all patients underwent simulation computed tomography (CT) performed by the TSRM with 16-layer Toshiba Aquilion CT with slice thickness of 2 mm.
The scans were acquired with the patient supine on a large carbon-fiber stand and immobilized with unblocked footrest, arms positioned along the sides with palm on the table, and thermoplastic mask (from the company Tema Sinergie) molded by collaboration of 2-3 radiology technicians. These scans were performed on a twin couch to the radiation treatment couch, on which it is possible to attach the same immobilization systems used in the simulation phase in order to ensure the reproducibility of the treatment itself, a fundamental goal of radiation therapy.
The CT images obtained were then subsequently transferred to the Varian Treatment Planning System (Eclipse®, Varian Medical System, Hansen Way, Palo Alto).

Treatment plan

"Contouring" the treatment volumes of the sample reports a mean GTV value of 4.80 cm3 (range: 0.17-24.69 cm3), while the mean value of spherical equivalent diameter, which considers the lesion as a pseudo sphere was 2.12 cm3 (range: 0.7-3.6 cm3).
The volume of 'clinical interest, i.e., CTV, is considered to be the same as GTV (gross tumor volume) because stereotactic treatment involves exclusive irradiation of the macroscopic lesion, while the Planning Target Volume (PTV) was generated by adding an isotropic margin of 3 mm to the GTV.
Based on the prescription given by the Radiotherapist, the Health Physicist then made the treatment plan of SBRT for each patient with dynamic 7-beam IMRT technique or VMAT technique, using the Eclipse Treatment Planning System and normalizing the dose to the mean target.

Different treatment schedules were used: 24 Gy and 27 Gy delivered in three sessions (8 Gy or 9 Gy per fraction), 25 Gy and 30 Gy in five sessions (5 Gy or 6 Gy per fraction). All patients were irradiated by C-LINAC OBI Linear Accelerator (Varian medical Systems Inc, Palo Alto, USA) equipped with multi-lamellar collimators (MLCs), 2 x 60 lamellae, with photons of energy 6 MV (Megavolt). Each session was preceded by Cone Beam CT (CBCT) to check correct patient positioning and with automatic realignment of the couch for correction of translational shifts. Regarding toxicities, treatment with stereotactic radiotherapy (SRT) was well tolerated by all patients, and no toxicities higher than G1 (grade 1) occurred.

Data collection.
Data were collected through a retrospective study with analysis of the medical records of each irradiated patient. Data regarding the recorded movements of treated patients were obtained from the record and verify software "ARIA."

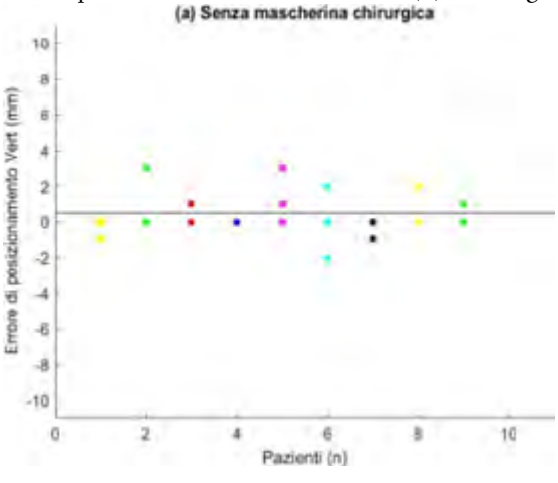
RESULTS

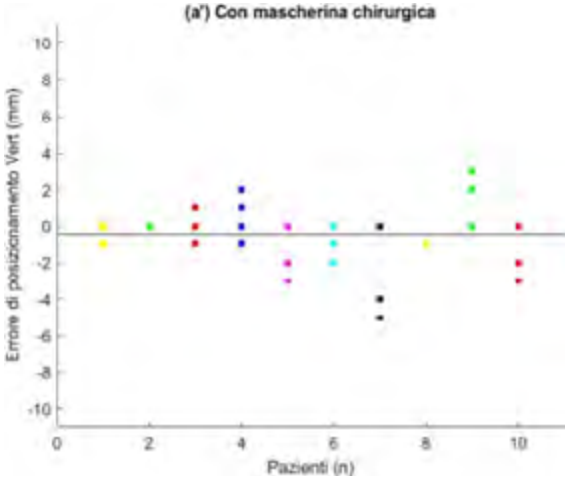
We analyzed the shifts along the three axes and calculated the mean and average standard deviation (SD Σ) values corresponding to the two groups of patients, without and with surgical mask

Errore di posizione		
Indice	Senza mascherina	Con mascherina
Vert (mm)	0.5 ± 0.9	-0.4 ± 1.0
Long (mm)	-0.3 ± 0.7	0.2 ± 1.1
Lat (mm)	-0.6 ± 1.0	0.1 ± 1.1

Table 1: *Position errors without and with surgical mask*

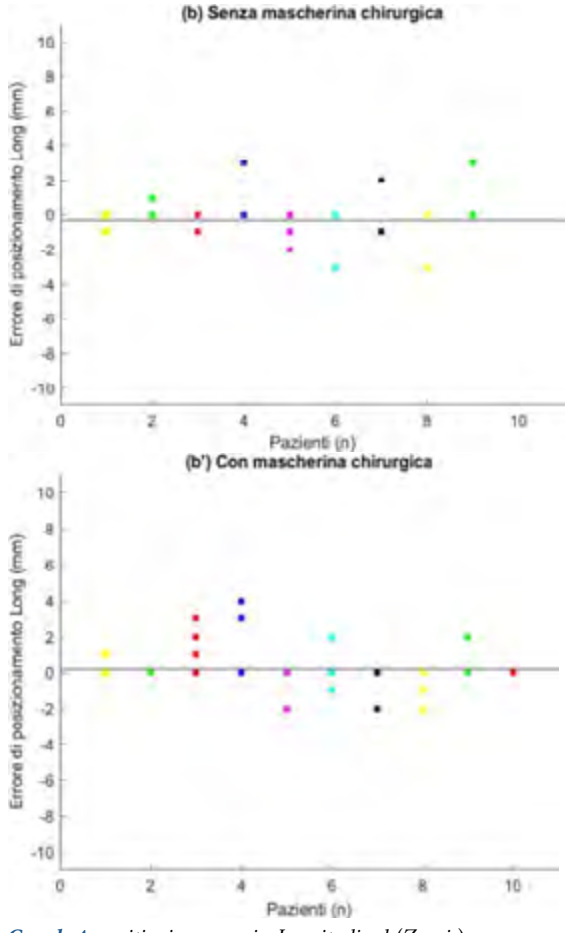
Next, on the MATLAB (matrix laboratory) programming and numerical computing platform, we represented plots in which translational displacements were entered.
Graph 3 shows the Verticality (Y-axis) positioning error calculated in each session in patients treated from November 2018 to early 2020 with only thermoplastic mask. Below is Chart 3 (a') showing





Graphic 3: *positioning error in Verticality* (*Y axis*)

the positioning error in Vertical in patients treated with combinatorial design of thermoplastic mask and surgical mask from June 2020 to March 2022. In the following images, the average of all averages in the vertical direction (VERT) is highlighted as a gray horizontal line, with a numerical value of 0.5 mm without surgical mask (A) compared with -0.4 mm with surgical mask (A')
In Graph 4, we observe the longitudinal (Z-axis)

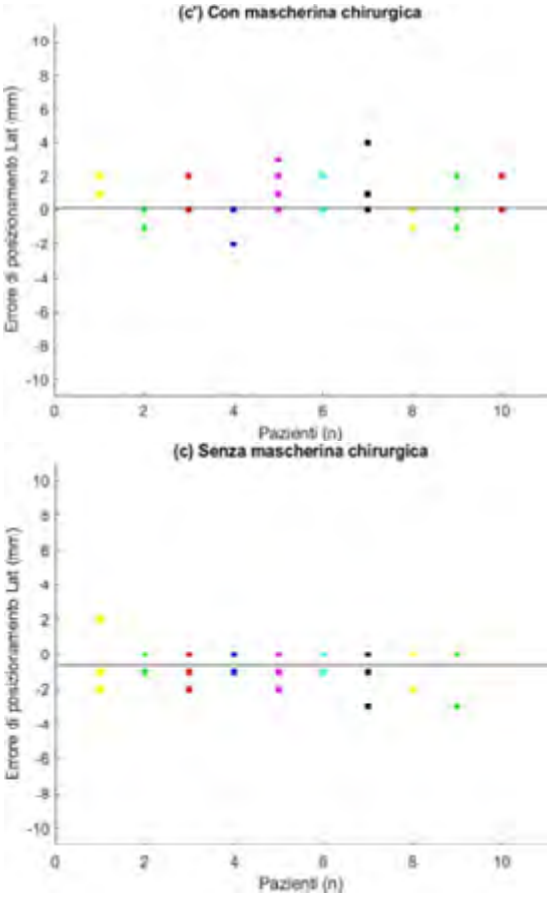


Graph 4: *positioning error in Longitudinal* (*Z axis*).

positioning error at each session in patients treated with thermoplastic mask only (b) and patients treated with the aid of surgical mask (b'). The average of all averages along the longitudinal translational axis (LONG) turns out to be without surgical mask

RESEARCH ARTICLE

-0.3 mm (B) and with surgical mask 0.2 mm (b').
In Graph 5, we detect the laterality positioning



Graph 5: *positioning error in Lateral (X axis).*

error (X-axis) in each session in patients treated with thermoplastic mask only (c) and patients treated with the aid of surgical mask (c'). The mean of the error averages along the lateral direction (LAT) without (c) and with surgical mask (c') is -0.6 mm compared with 0.1 mm.
Taking into account the fact that with our system we have the constraint of 1 mm for the evaluation of displacements, we calculated the % of translational position error with and without surgical mask greater than 2 mm, obtaining in vertical 20.0 vs 28.57%, in longitudinal 20.0 vs 28.57% and in lateral 20.0 vs 28.57%.
Thus, considering that the % of displacements greater than 2 mm is small in both cases, it is possible to say that indeed the differences are case-related and that being overlapping % there are no statistically significant differences in translational position errors without and with surgical mask, if set P > 0.05 (p-value).
Next, in 5 of 10 patients treated with surgical template below the thermoplastic mask, Kv (kilovolt) X-ray images were acquired to verify online the patient's position at the end of fractionated stereotactic treatment before removing the immobilization system used.
To complete the analysis of our sample, in order to confirm the reliability datum of the setup with the reproducibility datum of online in vivo dosimetry, we compared the dose fluence images transmitted from the integrated portal images during all sessions versus those acquired in the first treatment session.
The images produced by the EPID (electronic portal vision devices) were compared at the TPS (treatment planning system) workstation by taking advantage of the functions made available by the Varian ECLIPSE v1.01 Treatment Planning software through the "Portal Dosimetry" toolbox.
In the "Portal Dosimetry", the integrated images

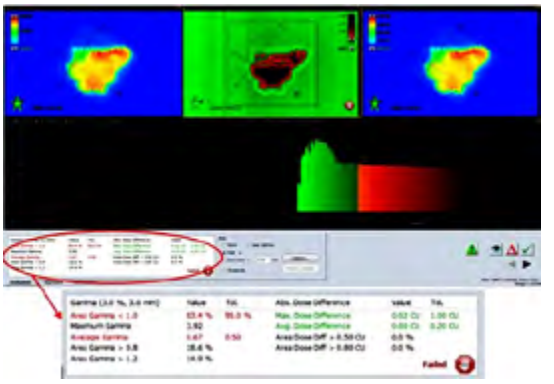


Figure 1: *Example of graphical user interface "Portal Dosimetry"*

of the fluence transmitted in different sessions and the reference images acquired in the first treatment session are shown at the top left and the reference images acquired in the first treatment session at the top right, respectively; in the center is displayed the gamma difference in absolute value and at the bottom, highlighted in the red circle, is the quantitative result of the gamma analysis comparing the two images.
Evaluating in comparison the Gamma Area value obtained with the acceptance criterion of 3% DA% (dose agreement) in 2 mm DTA (distance to agreement), we found an overall agreement on all the treatment ranges of the studied patients; especially, all the findings were above 99% overlap with an average value of 99.5%.

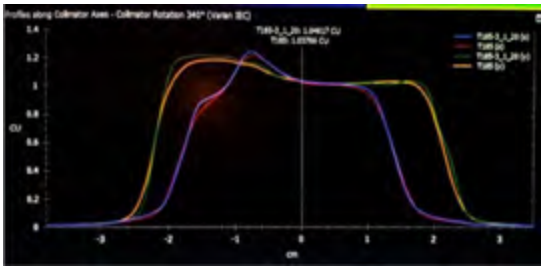


Figure 2: *Example of matching between dose maps referring to the T185 field with GAMMA analysis* (3.0%, 3.0 *mm*) *of* 99.7%

overlap with an average value of 99.5%.
Thus, the recorded data showed substantial overlap with the pre-treatment parameters with maximum displacements of 1 mm in all directions.
This observation highlights how the presence of the surgical template did not result in excessive discomfort to the patient, such as to result in movement during treatment delivery, and confirms the adequate maintenance of position and reproduci-

bility of stereotactic treatment in patients treated with PPE (personal protective equipment) in the Covid-19 era.
This establishes how even in such precise and accurate treatments as encephalic fractionated stereotactic this additional system allowed for maximum safety, reliability and precision in working.

DISCUSSION

The management of radiotherapy activity in the pandemic era is accompanied by numerous insights that make it possible to state without a doubt how the prevention of contagion was based above all on a new cultural philosophy, not only as a statement of intent, but as a real systematic strategy of communication, awareness and continuing education of the radiotherapy team and the patients themselves.
Analyzing the emergent picture in retrospect, we can recognize that these interventions were necessary and effective, allowing continuity of care to be achieved while simultaneously limiting the risks of clusters of contagions among patients and operators, in a constant effort to promote a culture of safety within the Operating Unit.
The psychological and relational role assumed by the TSRM (medical radiology health technician) in the reception of the person assisted has undoubtedly made the therapeutic process more "bearable," in a holistic view aimed at treatment compliance and thus better positioning. And in the light of the radiation protection attention dictated by Legislative Decree 101\2020, it follows how much this analysis was as current as ever and guarantor of any undue exposure despite the application of new protocols issued in urgency.

CONCLUSION

The present experimental work carried out at the U.O.C of Radiotherapy of Barletta, on the basis of international studies carried out on the subject and published in recent months, confirmed that the introduction of surgical masks, if associated with a correct and precise immobilisation procedure, does not lead to a statistically significant increase in set-up errors compared to pre-Covid 19 immobilisation.
Therefore, the strategies implemented proved to be essential both from the point of view of accuracy and precision required for this type of treatment and in terms of protecting operators and patients within the Operating Unit from infection.

RESEARCH ARTICLE

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