First, we would like to use this opportunity to address your concern about the susceptibility artifacts that have been present in our study. We have explained in our previous publications why we have interpreted the alterations on brain imaging of patients with coronavirus disease 2019 (COVID-19) detected on thin slices of the olfactory bulb-suppressed T1WI, pre- and postcontrast, as olfactory bulb injuries (blood-brain barrier and/or methemoglobin) and not artifacts. However, we will present these explanations again and also comment about some aspects of your Letter, as follows:

1. We understand the reason for your concern about susceptibility artifacts and confess that initially, we also had the same doubts as you expressed in your Letter when for the first time, we were faced with the images of these olfactory bulb injuries in patients with COVID-19.

2. To make sure that the findings we were identifying in the olfactory bulbs were real and represented an abnormality, we also reviewed the pre- and/or postcontrast fat-suppressed T1WI and STIR MR imaging from our data base of the orbits of healthy subjects obtained before the COVID-19 pandemic, and we explained these findings in our first publication.

3. Our research group performed another retrospective study not yet published (performed on 1.5T MR imaging) that show that the normal olfactory bulbs have signal intensity similar to that of the cortical gray matter in the sequence using thin-sliced coronal fat-suppressed T1WI (Fig 1A, arrows) with no contrast enhancement (Fig 1B, and Fig 2A, long arrows). On coronal thin-sliced FSE T2WI, in 90% of olfactory bulbs, the centrum ovale has hyperintensity similar to that in the cortical gray matter (Fig 1C and Fig 2B, superior extremity of lines) and the periphery has hypointensity of the white matter (Fig 1C and Fig 2B, horizontal short arrows). This aspect resembles the cell layers observed on histology of normal olfactory bulbs.

Susceptibility artifacts due to the interface between the bone and air were found in 81% of images in our study. All of these susceptibility artifacts were bilateral and symmetric, mainly at the topography of the cribriform plate outside and below the olfactory bulbs (Fig 1B, arrowhead and Fig 2A, short arrow) or the parasagittal region adjacent to the criatal galle and more frequently on postcontrast sequences. Forty-five percent of patients also presented with a kind of susceptibility artifact at the sphenoidal level that projected inside the base of the frontal lobe, being easily recognized as an artifact as you also showed in your axial T1WI performed at 3T. These susceptibility artifacts should not hinder the analyses of olfactory bulbs because they can be recognized.

4. So, as you seemingly know and in fact show in your figures on axial T1WI, artifacts can be easily recognized by radiologists and should not be confused with enhancement or methemoglobin. The susceptibility artifacts usually have ill-defined margins that eventually vanish and are often bilateral as you have shown in your axial Fig 1.

Anyone reviewing our figures (in the first publication, in our first reply, in our Letter, and also in our original study recently published) will realize that they show true lesions and not artifacts.

5. In your Letter, you wrote about susceptibility artifacts being worse on 3T brain MRI, and they are reduced and disappear in a minor magnetic field MRI machine such as 1.5T.

All of our patients’ brain MRIs were performed on a 1.5T machine, and this was clearly described in the Materials and Methods of our article on which you are commenting. Therefore, the brain MRIs of our cases may have fewer artifacts than yours because we used a 1.5T machine and you used a 3T machine. Perhaps this is the reason you have had difficulty with artifacts.

6. In the figures of your commentary and Letter, we were surprised because you showed figures using axial slices on T1WI, which are not adequate to analyze the olfactory bulbs. It would be better if you had shown this artifact in the coronal plane of your figures.

I would kindly ask you to look again at the figures in our publications because we included and analyzed only cases in which there was a sequence with thin slices on the coronal plane.

If the indication for brain MR imaging is to evaluate the olfactory bulbs, it is much better to analyze them in a coronal plane or use 3D acquisitions of the brain with reconstructions in the coronal and sagittal planes.

7. Our MRI findings, as well as other research findings, documented in vivo the hypothesis of Severe Acute Respiratory Syndrome coronavirus 2 in the olfactory bulbs as a cause of anosmia, even before the first anatomopathologic studies were allowed to be performed and published. And now, recently, the first histopathologic postmortem studies have confirmed our findings.

Lee et al demonstrated, in an extremely elegant postmortem histopathologic study using much more sophisticated tools (eg, an 11.7T scanner), what we had suggested in vivo previously on the 1.5T MR imaging. This postmortem histopathologic study showed microvascular injury with areas of fibrinogen leakage, thinned basal lamina, and hemorrhagic lesions in the brain and olfactory bulbs, which can explain our radiologic findings (olfactory bulb enhancement [breakdown of the blood-brain barrier] and/or probable hemorrhagic lesions [methemoglobin]).

In summary, we explained again, point by point, why our findings are not artifacts. We show new data with the features of a normal olfactory bulb on coronal T2WI which frequently has a hyperintense central area (similar to the cortex) surrounded by a hypointense layer (similar to white matter) and susceptibility artifacts at the cribral plate on coronal fat suppressed T1WI.

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We also commented on the Letter\(^1\) from our colleagues in Miami. Therefore, in closing, we would like to state that despite sometimes finding artifacts on MR imaging, an experienced radiologist would recognize the artifacts and have the obligation to communicate if find any other important information about the MR images (such as olfactory bulb injury seen in a retrospective study on MR imaging of patients with COVID-19 not investigated for anosmia but investigated for other neurologic complications in the beginning of this terrible pandemic) in an impartial manner. It is our obligation to present our findings to the scientific community without any preconceptions, recognizing MR imaging artifacts and differentiating them from what seemed true COVID-related lesions in the olfactory bulbs. Increasingly, the scientific community is accumulating proof that there is clinical, radiologic\(^2\)–\(^8\) (MR imaging in vivo\(^2\)–\(^8\) and in postmortem\(^9\)), and anatomopathologic\(^9,10\) evidence for the presence of injury to the olfactory bulbs in patients with COVID-19.

REFERENCES


