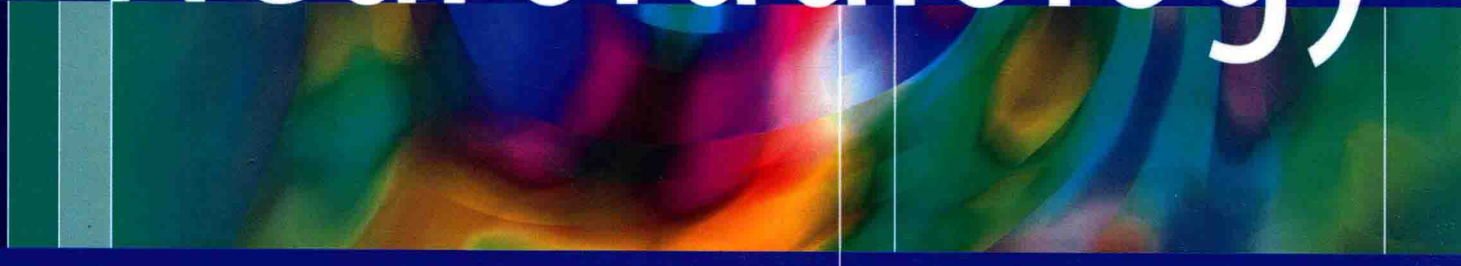
Fabio Triulzi
Cristina Baldoli
Cecilia Parazzini
Andrea Righini

Perinatal Neuroradiology



From the Fetus to the Newborn

Springer

Fabio Triulzi • Cristina Baldoli • Cecilia Parazzini
Andrea Righini

Perinatal Neuroradiology

From the Fetus to the Newborn

Springer

Fabio Triulzi
Department of Neuroradiology
Fondazione IRCCS Cà Granda
Ospedale Maggiore Policlinico
Milan
Italy

Cristina Baldoli
Department of Neuroradiology
IRCCS Ospedale San Raffaele
Milan
Italy

Cecilia Parazzini
Department of Radiology and Neuroradiology
Children's Hospital V. Buzzi
Milan
Italy

Andrea Righini
Department of Radiology and Neuroradiology
Children's Hospital V. Buzzi
Milan
Italy

ISBN 978-88-470-5324-3 ISBN 978-88-470-5325-0 (eBook)
DOI 10.1007/978-88-470-5325-0

Library of Congress Control Number: 2015956387

Springer Milan Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer-Verlag Italia Srl. is part of Springer Science+Business Media (www.springer.com)

Preface

This book originates from a very simple observation: for neuroradiologists which take care of neonatal brain, knowledge of what happens to the fetal brain, regarding both physiology and pathology, is essential to better understanding brain neonatal diseases. Nonetheless it is virtually impossible to assess the fetal brain by means of MRI without an appropriate knowledge of neonatal brain diseases.

Therefore, "prenatal and neonatal worlds" cannot be separated from both conceptual and practical point of view, but they should be studied together as a natural continuum regarding normal and pathological brain development.

From these considerations arises the subtitle: "from the fetus to the newborn". This is not a classical and exhaustive textbook, but more properly a collection of cases organized in a systematic way, so as to follow, from midgestation until birth, the fate of brain anomalies, highlighting how they may change during the course of gestation and how it may be difficult to predict how a lesion will eventually appear.

The cases are organized in a systematic index covering the most important prenatal and postnatal brain diseases from the congenital genetic based to the acquired ones. Some conditions are not treated, because still predominantly better assessed by ultrasound, such as malformations of the spine or, extremely rare, such as prenatal metabolic or neoplastic brain diseases. Together with fetal and neonatal MR cases, high-resolution images of fetal MR autopsy cases are presented, either as a reference for normal anatomy or as a gross pathologic confirmation of a previous fetal MR.

Milan, Italy

Fabio Triulzi
Cristina Baldoli
Cecilia Parazzini
Andrea Righini

Acknowledgements

This book could not have been concluded successfully without the support and collaboration of many people.
Special thanks go to our colleagues, gynaecologists, neonatologists and pathologists of our Institutions, Children's Hospital V. Buzzi, Policlinico Maggiore Hospital and San Raffaele Hospital in Milan.

We are grateful to our MRI technicians which strongly collaborated to guarantee the high quality of MR studies and showed an enormous patience and empathy with small patients, expectant mothers and parents.

Thanks to the parents and to the families for allowing the publication of the images, understanding the meaning and the importance of scientific divulgation.

Finally thanks to everyone who we could not mention but who are in our hearts as a source of inspiration and motivation.

Milan, Italy

Fabio Triulzi
Cristina Baldoli
Cecilia Parazzini
Andrea Righini

Contributors

Sabrina Avignone Department of Neuroradiology, Fondazione IRCCS Cà Granda, Ospedale Maggiore Policlinico, Milan, Italy

Claudia Cinnante Department of Neuroradiology, Fondazione IRCCS Cà Granda, Ospedale Maggiore Policlinico, Milan, Italy

Chiara Doneda Department of Radiology and Neuroradiology, Children's Hospital V. Buzzi, Milan, Italy

Özgur Öztekin Department of Radiology, Tepecik Education and Research Hospital, Izmir, Turkey

Silvia Pontesilli Department of Neuroradiology, IRCCS Ospedale San Raffaele, Milan, Italy

Elisa Scola Department of Neuroradiology, Fondazione IRCCS Cà Granda, Ospedale Maggiore Policlinico, Milan, Italy

Roberta Scotti Department of Neuroradiology, IRCCS Ospedale San Raffaele, Milan, Italy

Contents

Normal Development

1

Fabio Triulzi, Elisa Scola, and Sabrina Avignone

Fetal MR imaging covers a relatively long period of the fetal brain development: from approximately 18–19 gestational weeks (GW) until birth. Therefore, at present, it is possible to study more than a half of the entire gestational period by this technique.

Different authors and most of all, Catherine Garel, have reviewed systematically the normal development of the fetal brain as it appears on the MR images and reported normal biometrics curves as measured by MRI; gyration and myelination process has been extensively reported as well [1–6].

Here we present the fetal brain normal anatomy by means of MRI, with particular focus on the crucial period between 19 and 22 GW, taking into account the high-resolution images of MR autopsy (Fig. 1.1) as reference guideline to interpret the low-resolution fetal MR images.

1.1 Fetal MR Autopsy Technique

In order to prevent postmortem tissue autolysis, fetal MR autopsy studies were carried out within 24 h from death, without any fixation, in an intact fetus conserved in a refrigerator at 4–5°C prior to MR examination. The fetuses with spontaneous death in utero were not considered due to their long permanence at body temperature that accelerates the autolysis.

To obtain comparable images with the in vivo study, it is important to preserve the natural tissue contrast on T1 and T2-weighted images. The standard fixation with formalin causes a marked tissue dehydration and a modification of T1 and T2 contrast [7, 8]. On the contrary, an MR study performed within approximately 24–28 h from death without any fixation and with the fetal brain in situ, allows to maintain the normal contrast differences between tissues. It should however be noted that even though cooling may preserve fetal brain from autolysis, it nevertheless decreases the T1 and T2 contrast between tissues [9], and of course postmortem imaging cannot be considered the same as clinical imaging in a living being. The absence of blood pressure can change the shape of vessels and of the brain, resulting for example in a kinking of the brainstem. The vaginal delivery may cause deformation of skull and brain as well. Blood elements sediment and intravascular clots may finally occur [10].

To obtain a reasonable compromise between acquisition time in a clinical setting and spatial resolution, the total acquisition time of a fetal MR autopsy is approximately 80 min by using a 3.0 T magnet. The T2-weighted images shown in this chapter are obtained applying a turbo spin-echo sequence (TR 6500 ms; TE 120 ms; FA 90°; NEX 4, acquisition time 20 min.); the voxel size was $0.3 \times 0.3 \times 1.2$ mm, equal to a true spatial resolution of 0.10 mm^3 (100 nl).

1.2 Fetal Anatomy on MR Autopsy

On the T2-weighted images of the fetal MR autopsy with spatial resolution of 100 nl, not only the three layers usually recognizable on in vivo fetal MR are visible, but also layer number 1, the marginal layer (Fig. 1.2), and, at least between 19 and 28 GW, a thin hypointense layer in the most external part of the subplate (Fig. 1.3). According to Kostovic et al., this thin layer could represent thalamocortical axons in the superficial layer of subplate that are waiting to enter the cortical plate [11], but at present, no correlation between these images and corresponding pathological specimens is available.

If we compare the single-shot T2-weighted images of the in vivo fetal MR (Fig. 1.4) with the turbo spin-echo T2-weighted images of the fetal MR autopsy (Fig. 1.5), we can highlight some changes in tissue contrast in the period between 19 and 22 GW that are barely visible on in vivo studies. Between 19 and 20 GW, the internal capsule and in particular the posterior limb of the internal capsule (PLIC) is clearly more hypointense than surrounding lentiform nuclei

F. Triulzi (✉) • E. Scola • S. Avignone
Department of Neuroradiology,
Fondazione IRCCS Cà Granda, Ospedale Maggiore Policlinico,
Milan, Italy
e-mail: fabio.triulzi@policlinico.mi.it

F. Triulzi et al., *Perinatal Neuroradiology: From the Fetus to the Newborn*, DOI 10.1007/978-88-470-5325-0_1

and thalami (Figs. 1.5, 1.6, 1.7, 1.8, 1.9, 1.10, 1.11, 1.12, 1.13, and 1.14); this is of course not due to the presence of myelin, it develops later in the last phase of gestation, but probably to the differences in contrast between the relatively compacted unmyelinated fibers and the relatively poor synapse density of the basal ganglia and thalami. Starting from 21 to 22 GW, the anterolateral aspect of the thalami before and the mesial part of the lentiform nuclei shortly after, begin to decrease their signal intensity on T2-weighted images and consequently PLIC becomes scarcely visible (Figs. 1.15, 1.16, 1.17, 1.18, 1.19, 1.20, 1.21, 1.22, 1.23, 1.24, 1.25, 1.26, 1.27, 1.28, and 1.29).

The posterior part of the thalami is particularly hyperintese on T2-weighted images at 19–21 GW; sometimes, this aspect can be misinterpreted as a lesion on the in vivo fetal images (Figs. 1.8h and 1.10f).

The maximum contrast between the intermediate zone and the subplate is reached at 19–20 GW (Figs. 1.8, 1.10, 1.12, and 1.14) and then rapidly decreases. At 28 GW the periventricular areas, and notably in the peritrigonal regions, are clearly more hyperintense on T2-weighted images than the surrounding parenchyma. At this stage, the classical three-layers aspect is no more detectable, and the subplate seems to be formed by thin different layers (Figs. 1.30, 1.31, and 1.32).

1.3 From the Fetus to the Newborn: In Vivo Anatomy

As previously reported, the fetal in vivo development was extensively reviewed in different articles and books; it should however be noted that the obstacle to an accurate and reliable brain MR imaging in vivo during fetal life is not only related to the poor spatial resolution but also to the poor contrast resolution. The T2-weighted sequences typically used in fetal MR imaging are single-shot fast spin-echo or steady-state free precession 2D or 3D acquisitions both with a significant decrease of contrast resolution if compared with a turbo spin-echo sequence. This concept appears clear in the direct comparison between in vivo and ex vivo fetal MR images and also looking at the fetal MR in vivo imaging of the late gestation period (Figs. 1.33, 1.34, 1.35, and 1.36). In the case of Figs. 1.35 and 1.36, the spatial resolution is proportionally better than in the midgestation cases, but if we compare the contrast resolution of the single-shot fast spin-echo sequence of this fetal case with the T2-weighted image obtained with the traditional turbo or fast spin echosequence in the normal newborn (Fig. 1.37), the differences in contrast are quite obvious.

Modern MR imaging in newborns can at present take more advantage by the progressive widespread use of 3.0 T. Without relevant reduction of contrast resolution, the increase of signal-to-noise ratio of 3.0 T allows to significantly increase spatial resolution in a affordable acquisition time. The increase in tissue border definition and the overall better anatomical depiction in comparison with the 1.5 T magnet are well appreciable in Figs. 1.37 and 1.38.

It is well known how T1 relaxation time is influenced by the magnetic field and how tissues differences can be reduced at high field strength [12]; however, at 3.0 T, it has been demonstrated how the 3D T1-weighted sequence can maintain an optimal contrast resolution even in neonatal brain imaging [13]. Moreover, the increase in signal-to-contrast ratio can further reduce the size of the isotropic vowel even under the cubic millimeter, allowing extremely detailed reformatted images (Figs. 1.39. 1.40, 1.41, and 1.42). Normal anatomy and myelination obtained by in vivo MR in the newborns have been also extensively reviewed in different articles [14–16] and book chapters [17, 18], please refer to the figure legends for a detailed description.

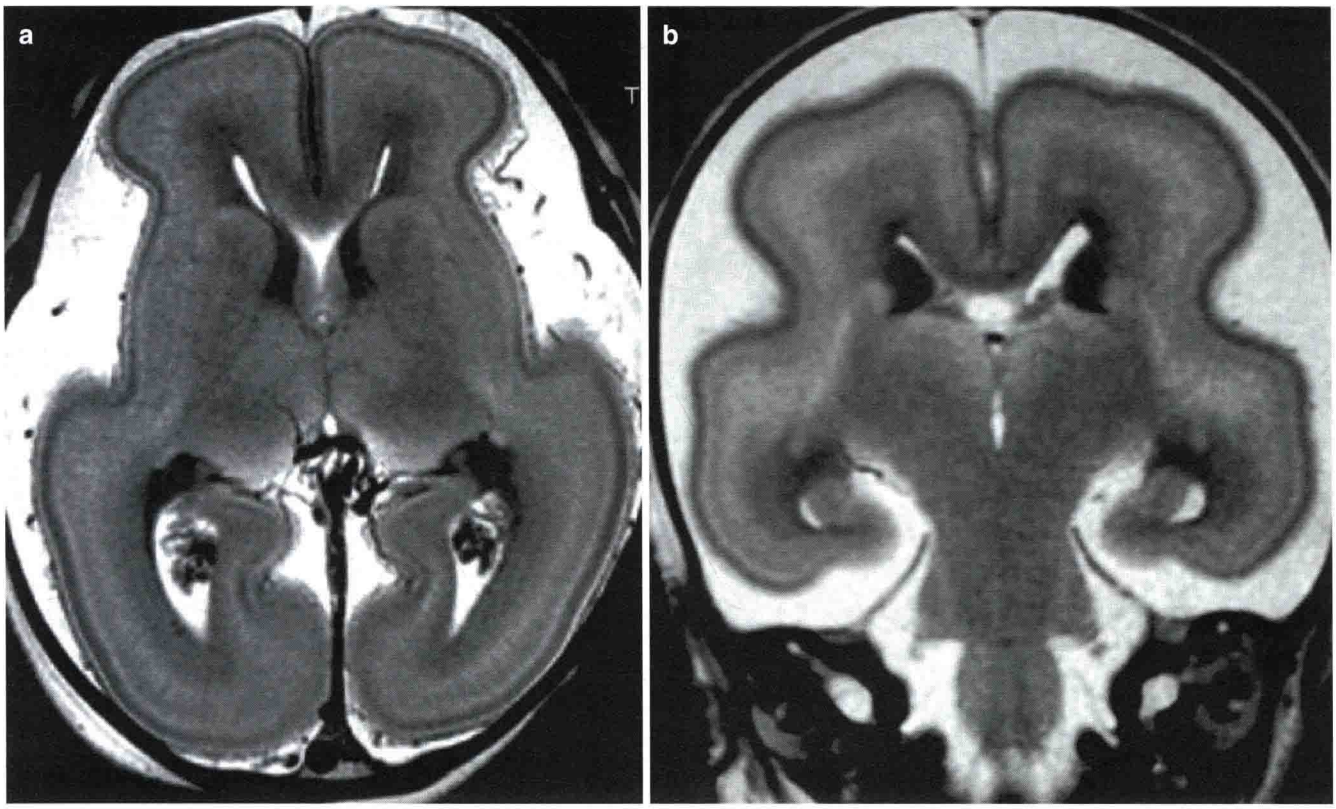


Fig. 1.1 Fetal MR autopsy. Normal brain at 22 gestational weeks (GW) (**a**) and 21 GW (**b**) on T2-weighted images. Voxel size 100 nl.

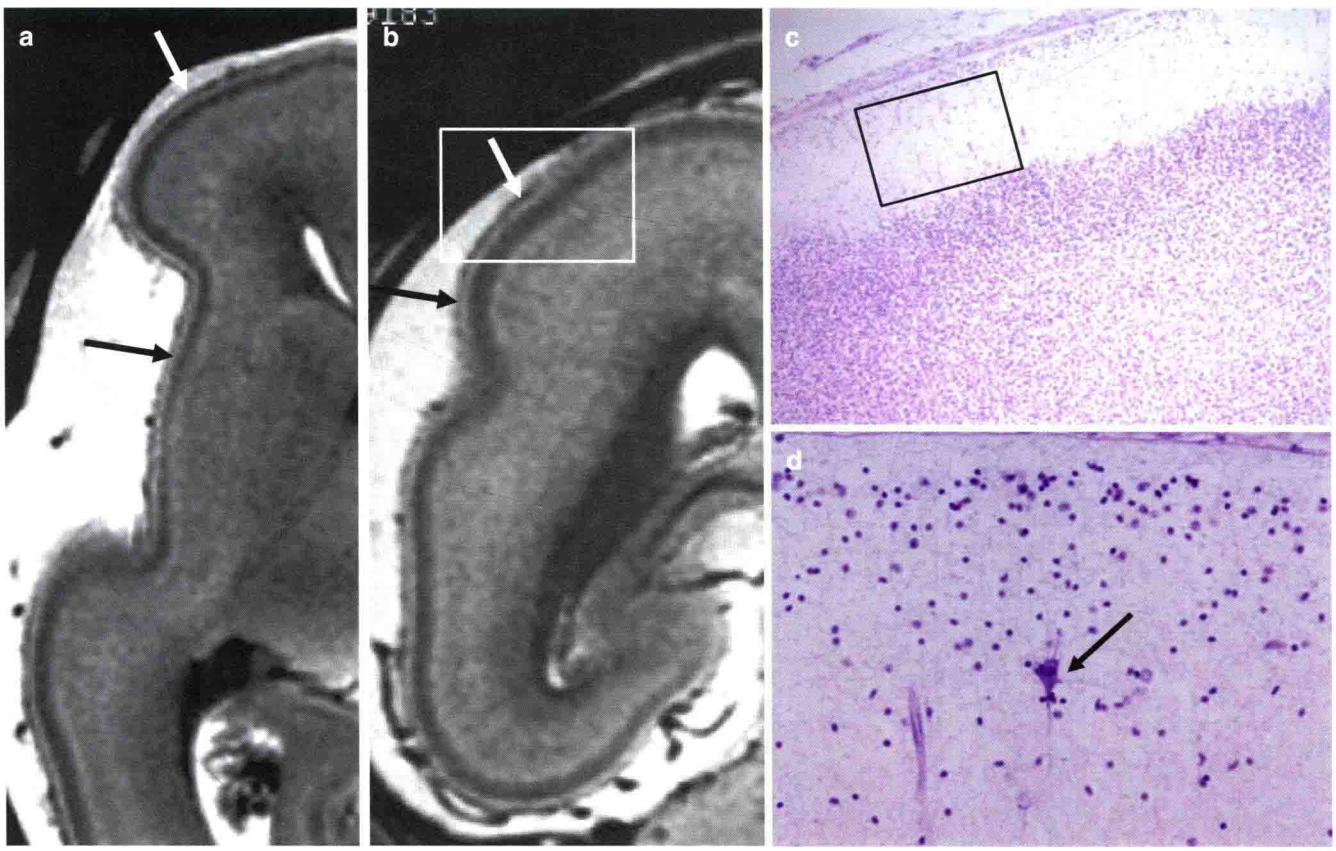


Fig. 1.2 Marginal zone on fetal MR autopsy (22GW). Layer I or marginal zone is detectable on fetal MR autopsy with a voxel size of 100 nl (*arrows* **a, b**). Correspondent histologic section stained with hematoxylin–eosin (**c**) and closeup view on marginal zone shows a large Cajal–Retzius cell (*black arrow*) (**d**) (courtesy C. Frassoni, Neurological Institute C. Besta, Milan)

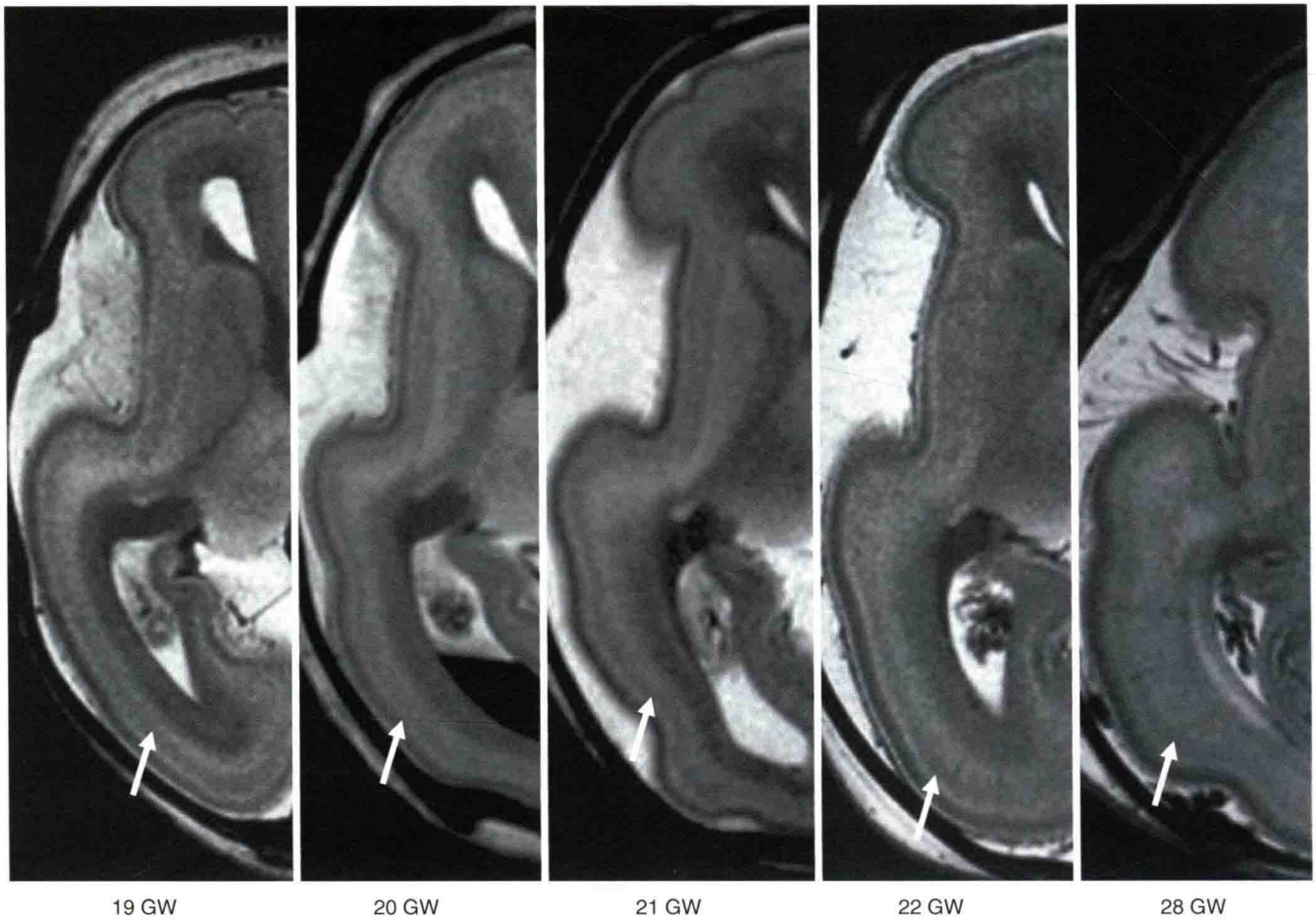


Fig. 1.3 A diffuse T2 hypointense layer on the more external part of subplate is recognizable on fetal MR autopsy between 19 and 28 GW (*arrows*). According to Kostovic et al., it could represent thalamocortical axons in the superficial layer of subplate that are waiting to enter the cortical plate

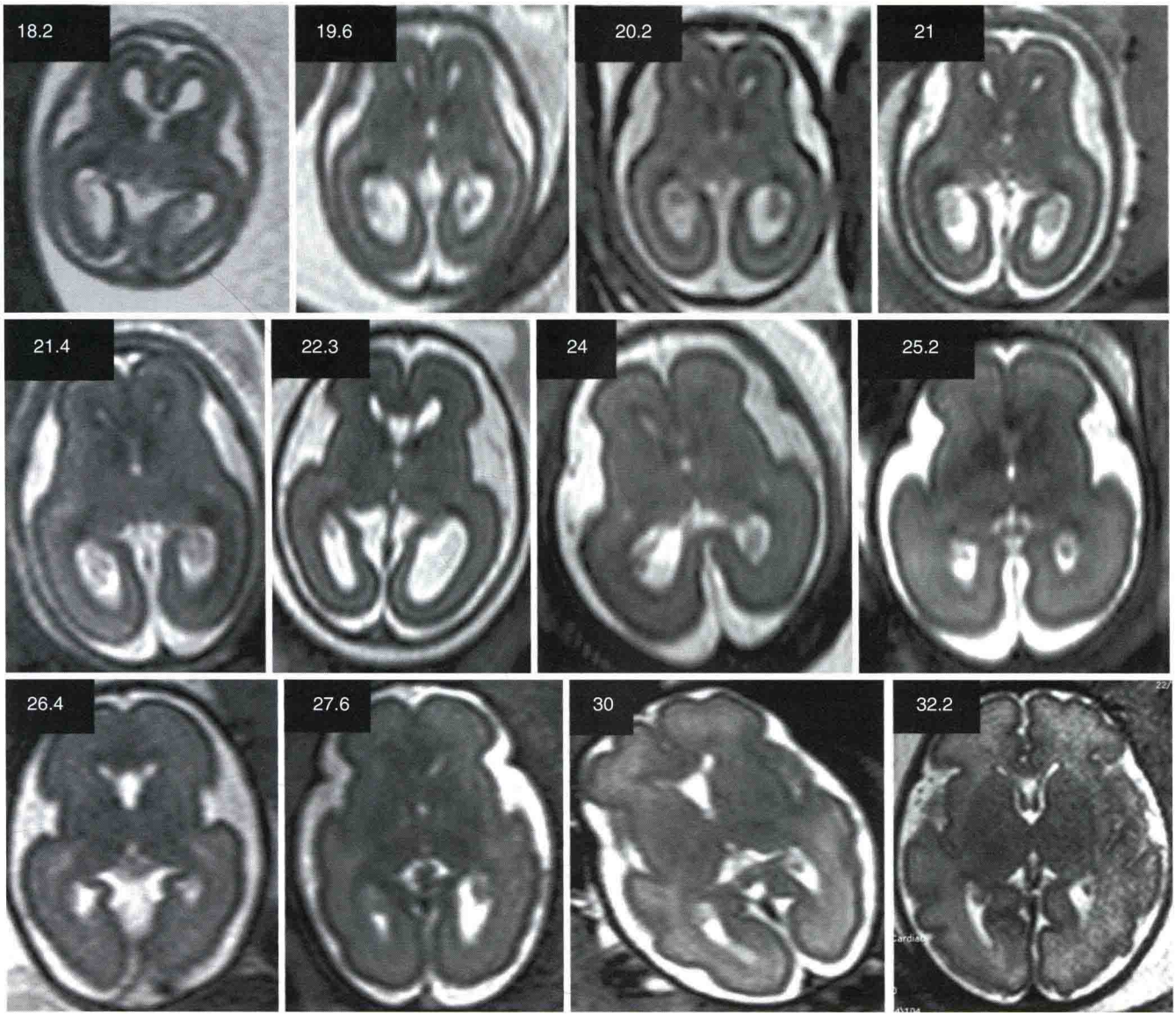


Fig. 1.4 Normal fetal brain development according to fetal MR. Twelve selected cases from 18.2 to 32.2 GW, axial T2-weighted images passing approximately through the thalamus. For the acquisition technique, see the text

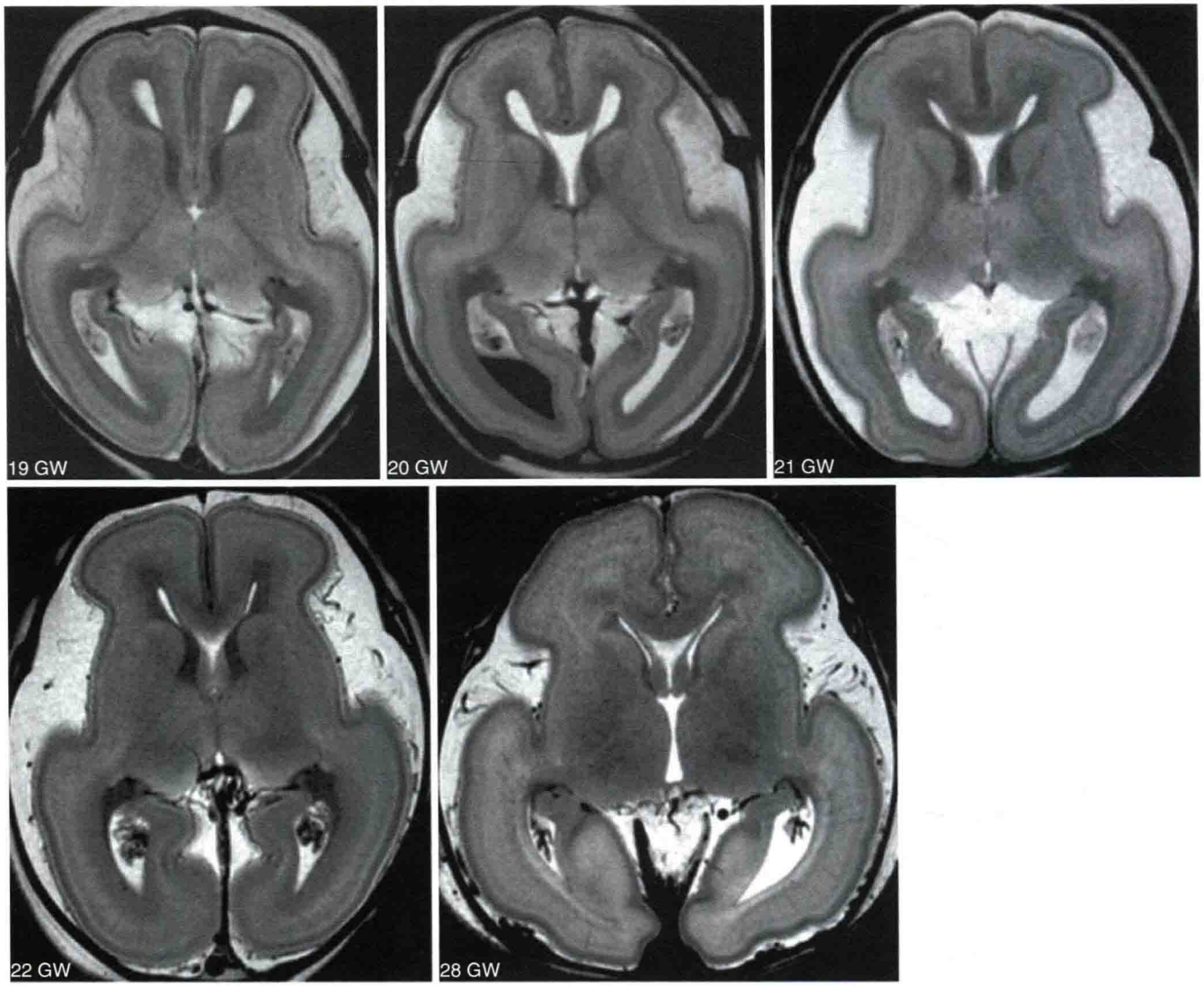


Fig. 1.5 Fetal MR autopsy. Normal cases at 19, 20, 21, 22, and 28 GW, representative axial T2-weighted images passing through the thalamus. Voxel size 100 nl. For the acquisition technique, see the text; all the cases are studied within 24 hours from termination of pregnancy (*TOP*)

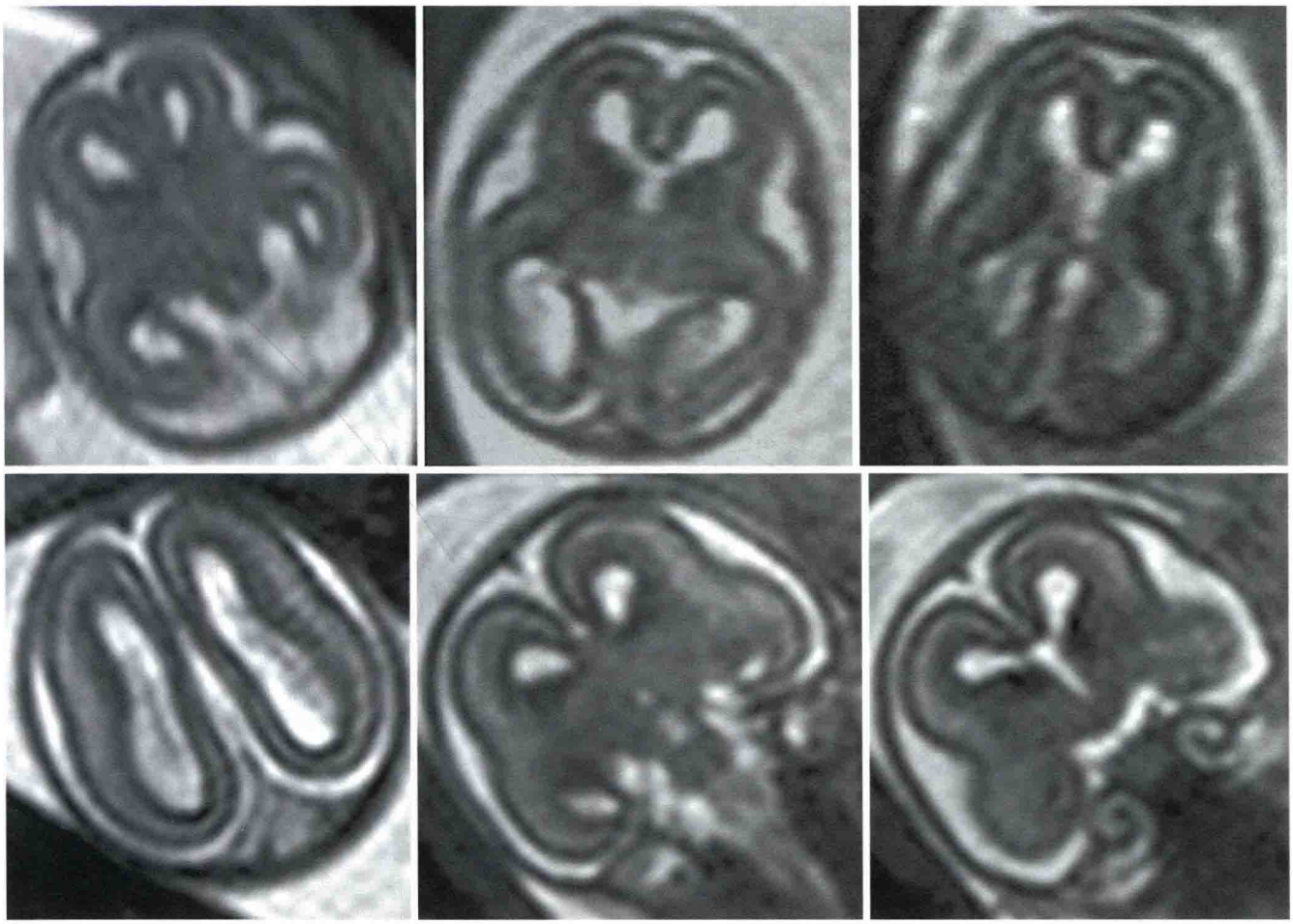


Fig. 1.6 Fetal MR, normal brain at 18.2 GW. Fetal MR is usually not performed before 19 GW. The fetal brain size is too small and the fetal movement is more pronounced. In this case, the parenchymal thickness is still relatively thin in comparison to the ventricular size (*top row*). T2 signal contrast differences between cortical plate, subplate, and intermediate zone are however already appreciable (*bottom row*)

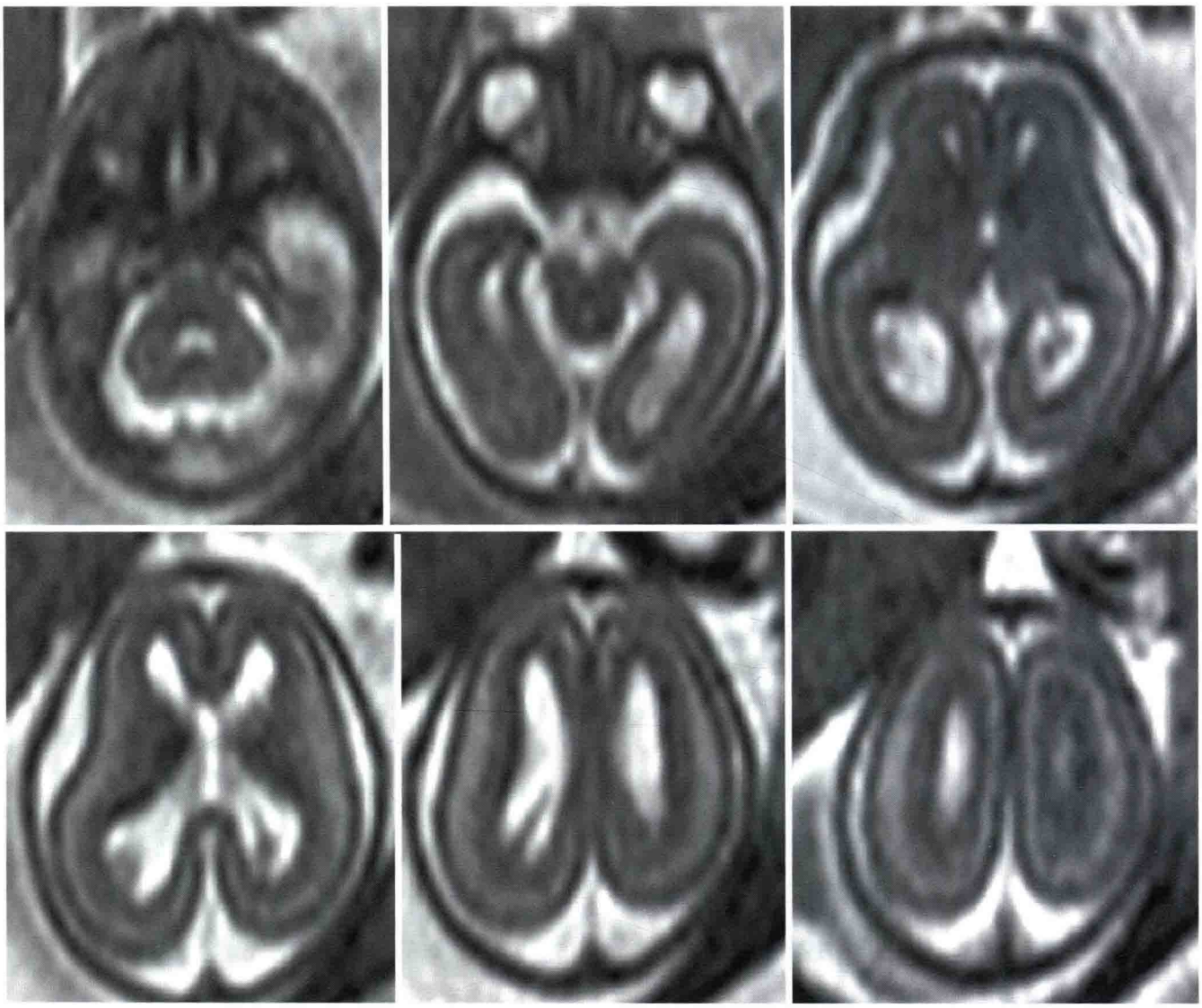


Fig. 1.7 Fetal MR, normal brain at 19.6 GW, axial sections. At this age, the main brain mantle layers, including germinal matrix, are usually well documented. Brain opercularization is going to become evident even though the surface of the brain is still substantially smooth