Postoperative Imaging

17

Kamil Karaali

17.1 Decompressive Craniectomy, Fat Graft

A 42-year-old female presented with right hemiplegia and aphasia.

17.1.1 Images and Legends

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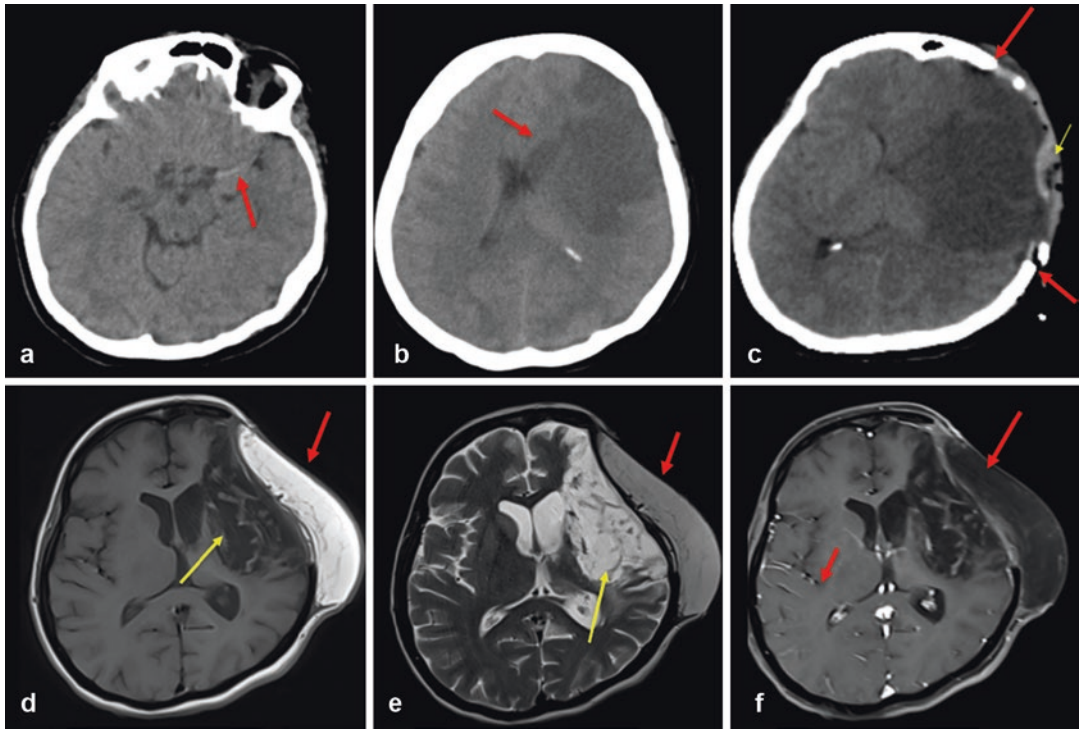

Fig. 17.1 A head CT after about 6 h from the start of the symptoms (**a**) show hyperdense left middle cerebral artery (MCA, arrow), which is an early indicator of a large MCA infarction. A day after (**b**), the infarction is prominent as hypodense areas, as well, left caudate head is hypodense and left lateral ventricle is compressed (arrow). A decompressive craniectomy is performed. Postoperative CT (**c**) shows bone defect (between red arrows) and air densities (yellow arrow). The defect was closed by resected calvarial bone 10 months after the first craniectomy, but osteomyelitis developed and it should be removed. Craniectomy defect was then closed with autologous fat tissue graft. An MRI was performed 11 months after the first CT. T1-weighted image (**d**) shows diffusely hyperintense fat graft (red arrow). Encephalomalacia is developed within the infarction area (yellow arrow). T2-weighted image (**e**) also shows diffusely hyperintense fat graft (red arrow). Encephalomalacia is close to fluid intensity (yellow arrow). T1-weighted fat suppressed image after contrast material injection (**f**) shows suppressed intensity of the graft. There is no pathologic enhancement

17.1.2 Clinical Management

- Decompressive craniectomy may be necessary in the management of strokes
- If the edema is remarkable, causing herniations or hydrocephalus due to fourth ventricle compression, decreasing the intracranial pressure is mandatory
- Large craniectomy defects are then closed by several type of materials. These include autologous bone, fat, fascia, and cranioplasty materials such as ceramics, alumina, bio-ceramics, polymers, and titanium. In this case, autologous fat was used

17.1.3 Imaging Findings and Differential Diagnosis

- Knowing the surgical technique and the type of the cranioplasty material is very useful for the evaluation
- Complications such as foreign material reaction and infection may occur after the surgery
- CT and MRI are frequently used to demonstrate collections, CSF leakage, and abscess formation
- An infection of the cranioplasty material needs resection, usually

Take-Home Messages

- Decompressive craniectomy may be necessary in the management of strokes
- Large craniectomy defects are closed by several type of materials
- There are various types of cranioplasty materials, such as autologous bone, fat, fascia, and cranioplasty materials such as ceramics, alumina, bio-ceramics, polymers, and titanium

Further Reading

- Khader BA, Towler MR. Materials and techniques used in cranioplasty fixation: a review. Mater Sci Eng C. 2016;66:315–22

17.2 Tumor Progress, Hematoma Within Resection Cavity

A 45-year-old male was being followed up for an intracranial mass. The mass was stable for the last four years. The patient developed severe headaches and MRI was performed.

17.2.1 Images and Legends

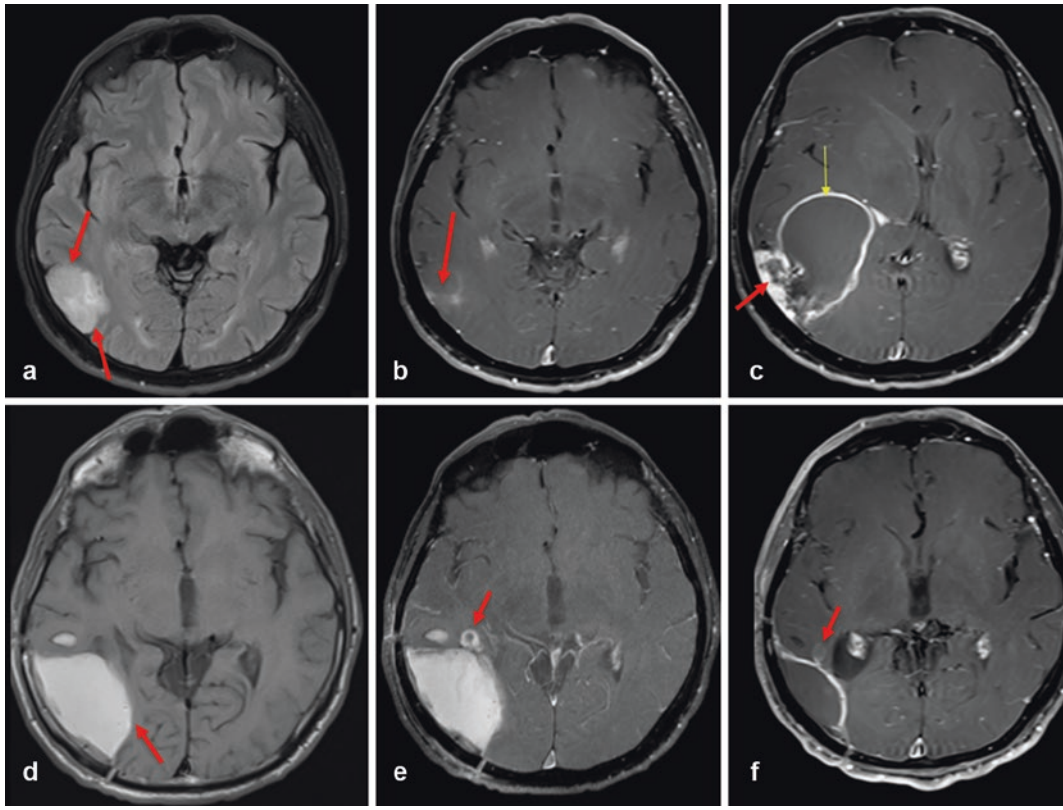

Fig. 17.2 FLAIR-weighted transverse (**a**) MR image shows a mass lesion on the right temporo-occipital junction. Tumor is peripherally located (arrow). On post-contrast T1-weighted MR image (**b**), there is mild linear enhancement centrally (arrow). The mass was stable on MRIs for the last four years. The patient was being followed up with yearly MRIs but he did not have the last scheduled MRI done. About 14 months after the last MRI, the patient developed severe headaches and an urgent MRI was performed. On this MRI, the mass was markedly enlarged, and has cystic, peripherally enhancing component (**c**, post-contrast T1-weighted image, yellow arrow), as well as peripheral solid component (**c**, red arrow). An urgent operation was done, early postoperative MRI was also performed. On T1-weighted image (**d**), there is homogeneous hyperintense area within the resection cavity, consistent with postoperative hematoma. On post-contrast T1-weighted image (**e**), there is a small nodular enhancement superior to the resection cavity, consistent with a small residual tumor. Five months after the operation, on post-contrast T1-weighted image (**f**); the size and the intensity of the hemorrhage is decreased, due to the resorption, as well, enhancement of the nodular residue is also decreased. Histopathologic diagnosis was anaplastic oligodendroglioma

17.2.2 Epidemiology/Most Commonly Seen Types

- Postoperative hematoma that causes neurological deficit is not very uncommon
- Its incidence is reported to be between 1 and 5%
- Usually, an immediate CT is obtained in almost every patient following the brain surgery
- A hematoma can be demonstrated as well as some other complications in this postoperative CT
- MRI is also recommended within 48 h after surgery, in order to show possible residual tumor and complications related to surgery

17.2.3 Pathology and Genetics

- Two most important complications of the brain surgery are hemorrhage and infarction
- Bleeding diathesis and some medications (e.g., anticoagulants) may increase the risk of postoperative hemorrhage
- Previous surgery also increases the risk of hemorrhage
- If the tumor is highly vascular, residue tumor tissue may also alter the hemostasis and cause hematoma within the resection cavity

17.2.4 Clinical Management

- Depending on the clinical status of the patient, hematomas could be reexplored and evacuated
- If the size is not too large and there is no related clinical deficit, follow-up may also be done
- The hemorrhage is usually resorbed and shrinked in several weeks, as in this case
- Another clinically important issue is possibility of rapid progress in a tumor, which was stable for years, as in this case. This was probably due to an "upgrade" in histopathology during follow-up period
- If a patient develops new neurologic symptoms during follow-up, an urgent MRI is necessary

17.2.5 Imaging Findings and Differential Diagnosis

- Hematomas are hyperdense on CT in acute and subacute phases
- The density decreases as the time proceeds, and within months, complete resorption is seen as hypodense areas on CT
- Depending on the MR imaging time, intensity of the hematoma varies on different sequences
- On hyperacute phase (less than 12 h) hemorrhage is isointense on T1-weighted images and isointense or hyperintense on T2-weighted images
- In the acute phase (12 h to 2 days) hemorrhage is isointense or hyperintense on T1-weighted images and hypointense on T2-weighted images
- In the subacute phase, on both sequences, hematoma is hyperintense, due to the methemoglobin formation
- Therefore, hematoma in the early postoperative MRIs is usually hyperintense on non-contrast T1-weighted images, as in this case
- As the hematoma resorption occurs, the intensity on T1- and T2-weighted images begin to decrease
- Hemosiderin formation begins at the periphery in late subacute phase, which is dark on T1- and T2-weighted images
- Sequences such as gradient echo T2 or SWI (susceptibility-weighted imaging) may also help in the detection of hemorrhage
- Hemorrhages may appear as restricted diffusion areas on DWI. In order not misinterpret as an infarction, all images should be evaluated, especially the non-contrast T1-weighted images

Take-Home Messages

- Postoperative hematomas are rare complications of brain surgery
- Hematoma appears differently on MRIs, depending on the imaging time. Usually, early postoperative MRIs is obtained within 48 h after surgery and hemorrhage is isointense or hyperintense on T1-weighted images in this period
- A previously stable tumor may show a rapid progress in size, during follow-up. This is probably due to an "upgrade" in histopathology

Further Reading

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17.3 Early Postoperative Hypophysis

A 33-year-old male with the history of suprasellar mass lesion is operated. Early postoperative MR imaging is performed a day after the surgery.

17.3.1 Images and Legends

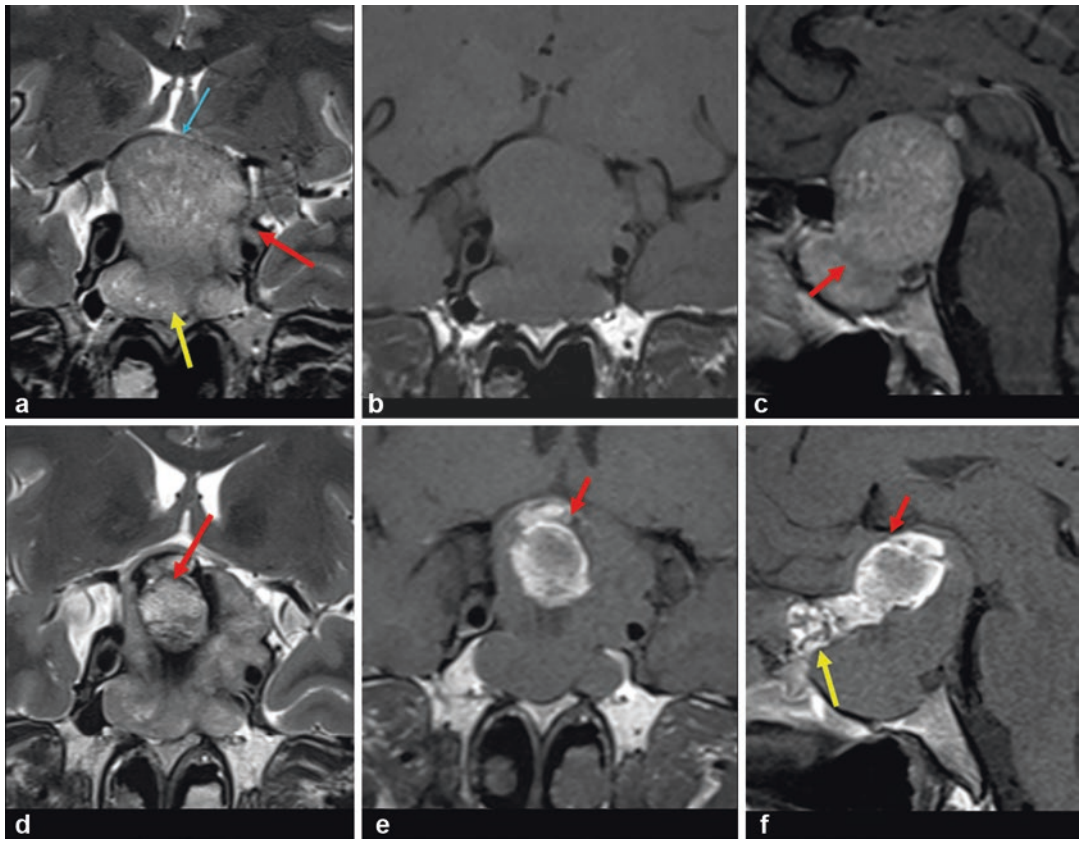

Fig. 17.3 T2-weighted coronal (**a**) MR image shows a large suprasellar mass lesion, a macroadenoma. The mass is homogeneously hyperintense. As well as the compression of optic chiasm (blue arrow), the mass is invading the sphenoid sinus (yellow arrow) and left cavernous sinus (red arrow). T1-weighted coronal (**b**) MR image shows that the mass is homogeneously isointense to brain parenchyma. On post-contrast sagittal T1-weighted image (**c**), the mas is enhancing intensely. The patient was operated by transsphenoidal approach. Postoperative images were obtained a day after. T2-weighted coronal (**d**) MR image shows hyperintense operation tract (arrow). Note hypointense hemorrhagic intensities (blood products) around the tract. Precontrast coronal T1-weighted image (**e**) shows hyperintense hemorrhagic intensities within operation cavity. On sagittal precontrast T1-weighted image (**f**), as well as the hyperintense hemorrhage (red arrow), surgical packaging material is also seen as heterogeneous hyperintensity (yellow arrow). Note, cavernous sinus component of the tumor is unchanged after the surgery. As well, there is residual tumor inferior to the hemorrhagic tract on sagittal postoperative image

17.3.2 Epidemiology/Most Commonly Seen Types

- Transsphenoidal surgery is the most common procedure for the treatment of pituitary macroadenomas
- In some selected cases, transcranial approach may still be preferred
- To evaluate the postoperative period, imaging characteristics of postoperative MR appearances should be known

17.3.3 Pathology and Genetics

- An early postoperative pituitary MRI after transsphenoidal surgery usually shows the surgical tract with hemorrhagic intensities
- Surgical packaging materials (fat, cartilage, gelfoam, etc.) are usually hyperintense
- Hemorrhage and surgical materials make the immediate postoperative images difficult to interpret
- The decrease in volume of the mass does not occur immediately after surgery. It may take 2–3 months to observe the full shrinkage
- The complexity of the early postoperative image also makes it difficult to identify the residue tumor
- It should also be remembered that, the portions of the tumor that extends into the cavernous sinus cannot be resected. Because of abundant hemorrhage risk, cavernous sinuses are avoided during the surgery

17.3.4 Clinical Management

- Early postoperative MRI of the pituitary is obtained in order to check possible complications of the surgery, as well as the residue tumors
- Some areas, as stated before, are avoided during the surgery and the portions of the tumor within those areas are left untouched
- Some residual tumors that are not within these areas and immediate second operation may be considered, before scarring and adhesions develop at the operation site
- MRIs show postoperative changes, as well as the possible residual tumor

17.3.5 Imaging Findings and Differential Diagnosis

- Preoperative and postoperative images should be compared thoroughly, to identify the changes related to surgery and possible residual tumors
- Hemorrhage within the surgical tract is usually hyperintense on both T1- and T2-weighted images
- There may be T2 hypointensities due to blood products, especially peripherally
- To control bleeding and prevent the CSF leaks, surgical packaging is frequently performed. Sellar floor and sphenoid sinus are usually filled with those materials
- Most of the surgical materials like autologous fat, cartilage, or gelfoam are hyperintense on T1-weighted images. To evaluate properly, information obtained from the surgeon will be very helpful
- Most surgical materials shrink with time
- Fat is usually absorbed completely after a year

Take-Home Messages

- Transsphenoidal surgery is the most common procedure for the treatment of pituitary macroadenomas
- To control bleeding and prevent the CSF leaks, surgical packaging is frequently performed. Most of these packaging materials (fat, cartilage, gelfoam, etc.) appear hyperintense on T1-weighted images. And most of them shrink with time
- Cavernous sinuses are avoided during transsphenoidal surgery. Tumor components within these areas will be seen as residual tumor postoperatively
- Early postoperative MRIs can show surgery-related changes as well as the residual tumors. Second immediate operation may be needed in huge macroadenomas with residual tumors

Further Reading

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17.4 Postoperative Abscess Development

A 16-year-old male with the history of intracranial mass lesion is operated. Early postoperative MR imaging is performed a day after the surgery. A month later, the patient developed high fever and headache. MRI was repeated.

17.4.1 Images and Legends

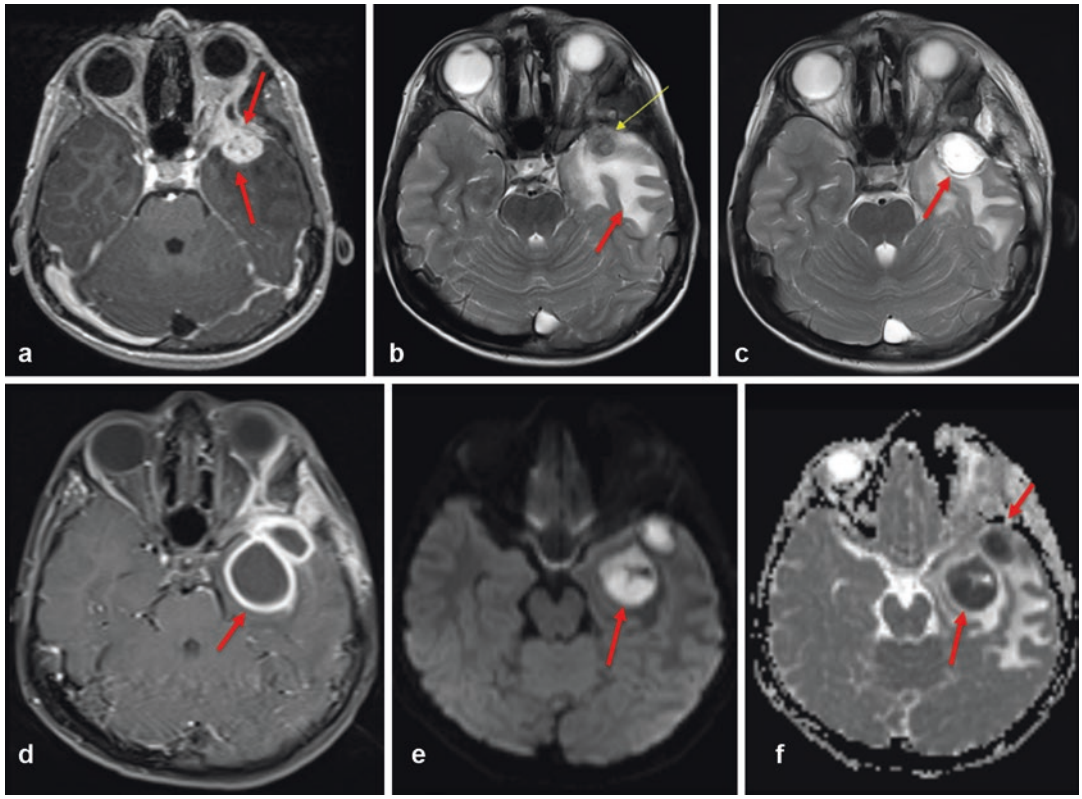

Fig. 17.4 T1-weighted post-contrast axial (**a**) MR image shows a mass lesion on the left anterior temporal fossa, behind the left sphenoid wing (arrow). T2-weighted axial image (**b**) shows surrounding vasogenic edema, the mass itself is hypointense (yellow arrow). Postoperative T2-weighted image (**c**) shows the resection cavity with fluid intensity. A month later, patient developed high fever and headache. MRI was repeated. T1-weighted post-contrast axial image (**d**) shows bilobulated lesion with marked peripheral enhancement. Inner contours of the enhancing margins are regular. On diffusion-weighted images (B1000 image, **e** and ADC map, **f**) there is marked diffusion restriction within the lesion (arrows)

17.4.2 Epidemiology/Most Commonly Seen Types

- Postoperative infection is a serious complication of brain surgery
- The incidence of postoperative infection is reported to be between 0.8 and 7%
- Most common symptoms are fever, headache, mental status change, seizures, and purulent drainage from the surgical wound
- Several types of postoperative infections may be seen: Subdural/epidural empyemas, meningitis, abscess, wound, or bone flap infections
- Early diagnosis of the type of the infection is necessary in order to plan the probable intervention, along with the antibiotherapy
- MRI is mandatory in the evaluation

17.4.3 Pathology and Genetics

- A typical abscess cavity shows peripheral enhancement with fluid intensity inside the lesion
- On DWI, abscess fluid usually show restricted diffusion. However, it is very important to remember that postoperative abscess may not show restricted diffusion
- The ratio of restricted diffusion is much higher in spontaneous abscesses than postoperative abscesses. Therefore, if the clinical findings suggest an infection, a peripherally enhancing fluid collection may be considered an abscess, even if restricted diffusion is not present
- Abscess margins usually show lower perfusion values than the tumors
- On SWI (susceptibility-weighted imaging), abscess margins have low intensity rims, which may also help for the differentiation

17.4.4 Clinical Management

- Along with the proper antibiotherapy, abscess cavities should be drained
- Antibiotherapy may be modified according to microbiologic evaluation of the abscess content. In this case, gram-positive cocci was present in the cavity fluid

17.4.5 Imaging Findings and Differential Diagnosis

Abscesses may look like peripherally enhancing or cystic tumors. Some clues to differentiate an abscess from tumor are:

- Abscesses have more regular enhancing margins, especially the inner contours, whereas tumors have usually irregular margins
- There is usually restricted diffusion within the abscess content. However, it is not a rule, especially in postoperative cases
- Abscess margins have lower perfusion values than tumors
- On SWI, abscess margins have low intensity rims

Take-Home Messages

- Urgent MRI is mandatory if a brain surgery patient develops fever, headache, personality changes, or seizures
- There are many types of postoperative infections and MRI gives valuable information for the differential diagnosis
- Typical postoperative brain abscess has regular, enhancing walls with fluid content. On DWI restricted diffusion may be present within the fluid portion

Further Reading

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17.5 Postoperative Dural Enhancement

A 40-year-old male with the history of intracranial mass lesion (which is diagnosed as glioblastoma multiforme) is operated. Early postoperative MR imaging is performed a day after the surgery.

17.5.1 Images and Legends

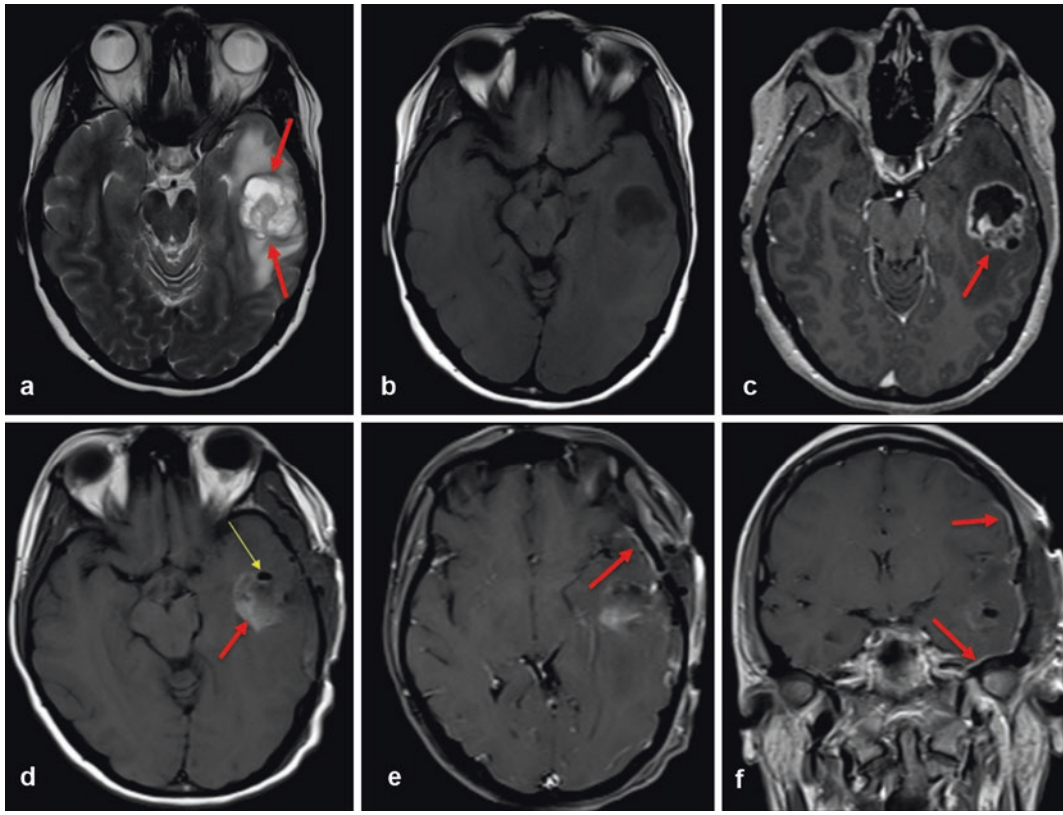

Fig. 17.5 MRI Images of T2-weighted (**a**), T1 (**b**), post-contrast T1 (**c**) images show a mass lesion on the left temporal lobe, which has cystic and solid portions with intense peripheral enhancement (arrows). There is no dural enhancement in preoperative images. After a day, early postoperative MRI shows resection cavity with hemorrhagic intensities (red arrow, **d**) and air (yellow arrow, **d**). On transverse (**e**) and coronal (**f**) post-contrast T1-weighted images, there is thin, asymmetric dural enhancement on the left side (arrows)

17.5.2 Epidemiology/Most Commonly Seen Types

- Two different types of extra-axial enhancement may be observed on postoperative MRIs: Thick (dural) and thin (leptomeningeal)
- Both types are observed very frequently after cranial surgery
- As well as surgery, stereotaxic biopsy, shunt catheter placement, and even lumbar punction may cause reactive dural enhancement

17.5.3 Pathology and Genetics

- Dural structures do not have blood-brain barrier and may show very thin and discontinuous enhancement in normal patients
- Surgery and hemorrhage may induce local inflammation on dura and vasodilatation and reactive changes develop afterwards. This causes thicker and more prominent appearance of dura on MR images

17.5.4 Clinical Management

- Dural thickness may be up to 3 mm in early postoperative period and may reach 6 mm within months, it is expected to decrease thereafter
- Thick dural enhancements persisting for year have been reported
- Dural enhancement alone does not require intervention

17.5.5 Imaging Findings and Differential Diagnosis

- Leptomeningeal enhancement is thin linear enhancement surrounding the gyral structures
- Dural enhancement is parallel to the inner table of calvarium and does not extend into the sulci
- Sometimes it can be difficult to differentiate residue or recurrent meningiomas from thick dural enhancements
- Cortical veins may also appear like dural enhancement in post-contrast T1-weighted images, especially if fat suppression is present. However, cortical veins are not seen on contiguous slices whereas dura is continuous

Take-Home Messages

- Early postoperative MRIs frequently show reactive dural enhancement
- Thickness of dural enhancement after the operation may reach 6 mm within months but decreases thereafter
- Dural enhancement rarely persists years after the surgery

Further Reading

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- Smirnotopoulos JG, Murphy FM, Rushing EJ, Rees JH, Schroeder JW. Patterns of contrast enhancement in the brain and meninges. Radiographics 2007;27:525–5
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17.6 Postoperative Infarction

A 36-year-old male with the history of intracranial mass lesion is operated. Early postoperative MR imaging is performed a day after the surgery.

17.6.1 Images and Legends

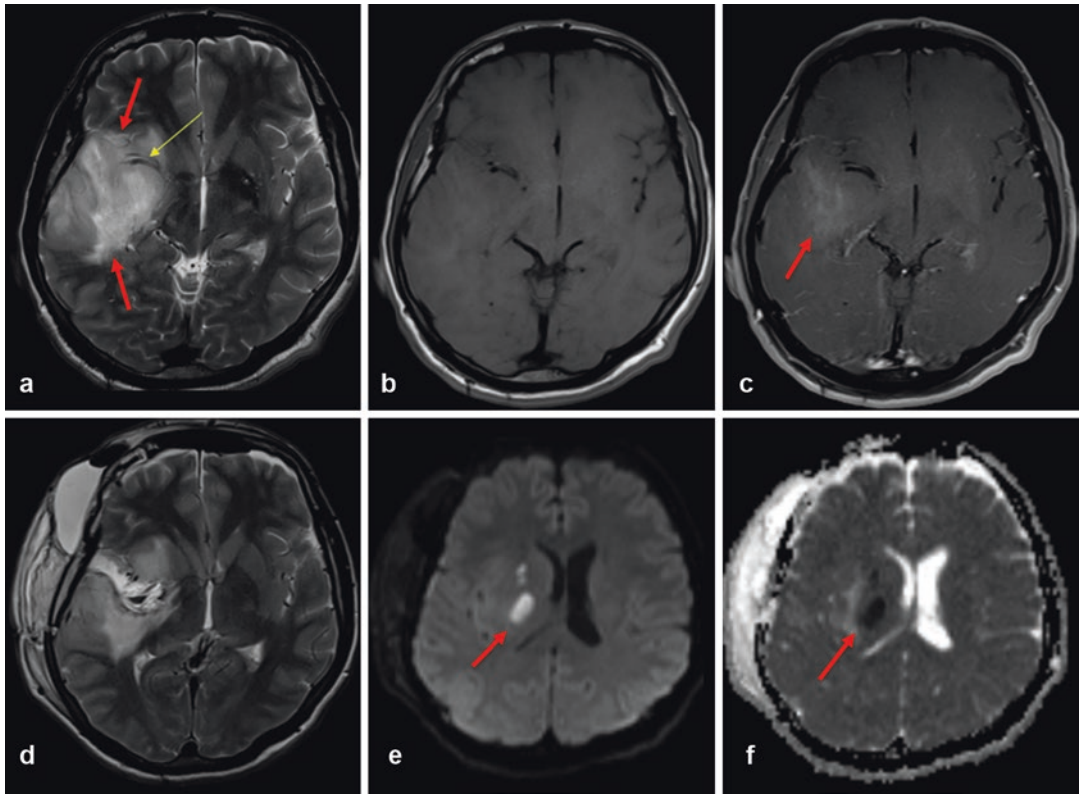

Fig. 17.6 T2-weighted (**a**), T1-weighted (**b**), post-contrast T1-weighted (**c**) MR images show a mass lesion on the right cerebral hemisphere around right Sylvian fissure (between red arrows) with a mild contrast enhancement (**c**, arrow). Right middle cerebral artery is passing through the mass (**a**, yellow arrow). After a day, early postoperative MRI shows the resection cavity. Edema and CSF leakage is also noted within the paracalvarial soft tissue (arrow, **d**). Just above the resection cavity, restricted diffusion is present on DWI (arrows on **e**: B1000 image, **f**: ADC map)

17.6.2 Epidemiology/Most Commonly Seen Types

- Majority of cerebrovascular incidents in brain tumor patients are related to treatment
- Infarctions are not infrequent postoperatively and they may be clinically silent, or may have subtle clinical findings. Therefore, they are usually identified on postoperative MRIs
- Diffusion-weighted sequences show restricted diffusion due to cytotoxic edema and they are the most valuable MRI sequence for showing cerebral infarctions in the early period
- Frequency of the postoperative infarctions is between 19 and 64%
- Infractions usually direct result of surgery. However, the patient's underlying stroke risk may also be increased by surgery

17.6.3 Pathology and Genetics

- Two most important complications of the brain surgery are hemorrhage and infarction
- Infarctions usually occur at the early postoperative period
- In cancer patients, it is known that thrombosis risk is increased. As well, arterial structures may also be compressed (as in the patient presented) or infiltrated by tumor, which also increase the likelihood of occlusion
- The infarctions usually occur around the resection cavity; however, remote infarctions have also been reported after cranial surgery

17.6.4 Clinical Management

- Cerebrovascular incidents after brain surgery increase the mortality and morbidity
- Early detection is important for the appropriate management
- Along with the medical treatment, decompression surgery may also be necessary if the infarction is large, and compression is remarkable
- External ventricular drainage is also performed if CSF flow obstruction is present due to the compression

17.6.5 Imaging Findings and Differential Diagnosis

- Restricted diffusion is the main finding of the acute brain parenchymal infarctions
- They appear bright on diffusion (e.g., B1000)-weighted images and dark on ADC (apparent diffusion coefficient) maps
- Findings begin to be detected 2–3 h after the incident. Other sequences such as T2 and FLAIR also show intensity changes but much later than the diffusion-weighted images
- Early postoperative MRIs should include diffusion-weighted sequences
- In early postoperative period, brain MRIs may be difficult to interpret, because hemorrhage may appear as areas of restricted diffusion; therefore, evaluating all the sequences along with the diffusion-weighted images is mandatory
- Hemorrhage is usually bright on T1-weighted images and dark on T2-weighted images in this period
- Sequences such as gradient echo T2 or SWI (susceptibility-weighted imaging) may also help in the detection of hemorrhage

Take-Home Messages

- Early postoperative (within 48 h after surgery) MRI should be obtained in all brain tumor patients who had surgical resection. Surgery-related enhancement is minimal in this period. Therefore, residual tumor detection is easier than later MRIs
- As well as showing the presence of a residual tumor, early postoperative MRIs are also valuable in showing complications such as hemorrhage, infarctions, and CSF leakage
- Diffusion-weighted images should always be included in the early postoperative MRI. Strokes may be undetected without these sequences
- Most infarctions after brain surgery is around the resection cavity; however, remote infarctions have also been reported

Further Reading

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17.7 Recurrent Tumor

A 56-year-old male with the history of intracranial mass lesion is operated. Preoperative and follow-up MRIs were obtained after the surgery.

17.7.1 Images and Legends

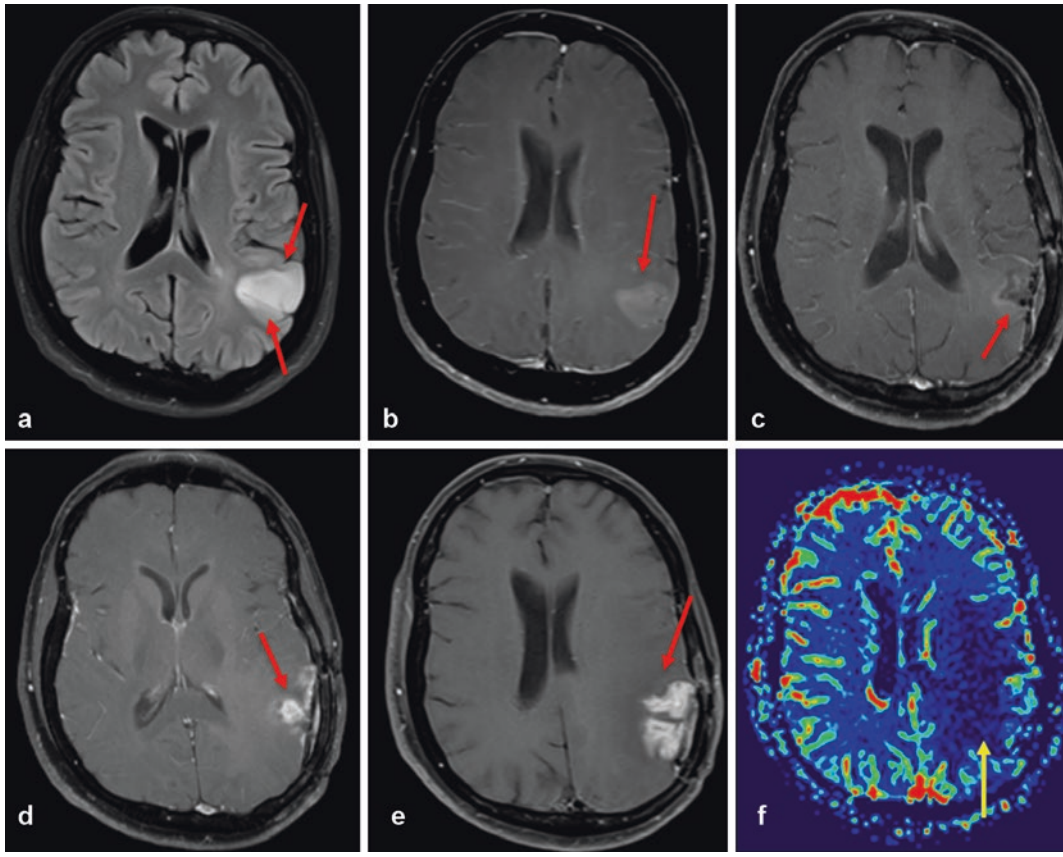

Fig. 17.7 FLAIR (**a**) MR image shows a mass lesion on the left parietotemporal junction. Tumor is peripherally located (arrow). On post-contrast T1-weighted MR image (**b**), there is mild enhancement (arrow). The patient was operated and the mass was completely resected. Pathologic diagnosis was anaplastic astrocytoma (WHO grade 3). Nine months after surgery, T1-weighted post-contrast MR image (**c**) shows no enhancement within or around the resection cavity. However, 15 months after the surgery, there is nodular enhancement within the resection site (arrow, **d**). And 18 months after the surgery, enhancement is much larger than previous MRI (arrow, **e**). Note: On perfusion MRI, there is no increased rCBV on the enhancing area (arrow, **f**). The patient was reoperated and pathologic examination confirmed recurrent tumor

17.7.2 Epidemiology/Most Commonly Seen Types

- Malignant gliomas (WHO grade 3 astrocytomas) and glioblastoma multiforme (WHO grade 4) have poor prognosis and this is mainly due to their extremely high recurrent rates
- Most recurrences occur within first year after the surgery
- MRI evaluation plays a very important role in the detection of recurrence

17.7.3 Imaging Findings and Differential Diagnosis

- Early postoperative MRIs is obtained usually within 48 h after surgery. This time interval is optimal for the early evaluation, because surgery-related enhancement is minimal
- Enhancing components of the possible residual tumor is evaluated much easier in early postoperative MRIs than later MRIs
- Opinion of the surgeon is also very important about the presence of residual tumor
- Even if the tumor is totally resected and no gross tumor left, recurrence still may occur, as in this case
- Reoperation of the recurrent tumor increases the median survival time
- Adjuvant chemo- and/or radiotherapy may also be added

Take-Home Messages

- Recurrence is the formation of tumoral mass after complete resection of the primary tumor
- Increased edema around the resection site and nodular enhancement are important signs of recurrence on MRIs
- On perfusion MR imaging, there is usually an increased rCBV in the recurrent tumors; however, there may still be a recurrence without increased perfusion, as in this case

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17.8 Postoperative Residue and Progress

A 47-year-old male with the history of intracranial mass lesion is operated. Preoperative and follow-up MRIs were as follows.

17.8.1 Images and Legends

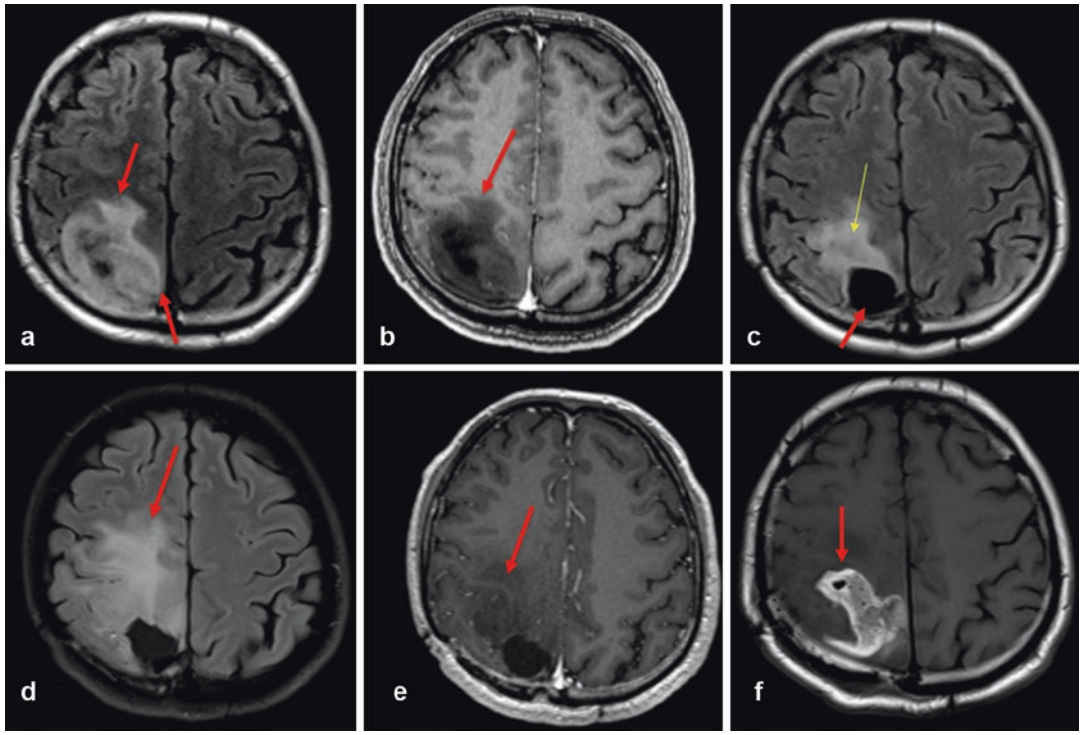

Fig. 17.8 Axial FLAIR (**a**) MR image shows a mass lesion on the right frontoparietal area (arrow). On the post-contrast T1-weighted image (**b**) there is no enhancement. MR examination on the fourth month after the surgery showed resection cavity (red arrow, **c**, axial FLAIR image) and residue tumor anterior to the resection site (yellow arrow, **c**). Patient was followed up with serial MRIs. The residue tumor increased on follow-up MRIs. Axial FLAIR image 18 months after the first surgery shows enlargement of the residue tumor volume (Arrow, **d**). There is still no contrast enhancement (post-contrast T1-weighted image, **e**). The patient was reoperated, postoperative T1-weighted axial image shows hyperintense hemorrhage within the resection cavity. Pathologic diagnosis was anaplastic astrocytoma (WHO grade 3) for both surgical excisions

17.8.2 Epidemiology/Most Commonly Seen Types

- Surgery is usually the main therapy in most brain tumors
- Depending on the pathologic evaluation, chemotherapy and radiotherapy may also be necessary
- The tumor cannot always be resected completely
- A patient's prognosis is better when all of the tumor can be surgically removed. There are four types of brain tumor surgery classifications:
  1. Gross total: The entire tumor was removed. Microscopic cells may still remain
  2. Subtotal: Large portions of the tumor were removed
  3. Partial: Only a part of the tumor was removed
  4. Biopsy only: Only a small portion, used for pathologic evaluation, was removed
- The amount of the residual tumor affects the prognosis, especially in high-grade glial tumors. As well, residual tumors may become larger in the follow-up period, which is considered as "progress."
- In the follow-up period, histopathologic grade of the residue tumor may also increase and this is considered as an "upgrade."
- If a previously non-enhancing tumor begins to show enhancement on follow-up, this is highly suggestive for tumor upgrade

17.8.3 Clinical Management

- Depending on the clinical findings, progress may need reoperation
- If imaging also suggests an upgrade, more aggressive treatments may be necessary. However, benefits of reoperation, especially in high-grade gliomas is still controversial

17.8.4 Imaging Findings and Differential Diagnosis

- In order to evaluate the possible residual tumor evaluation, first and foremost thing to know is the preoperative imaging characteristics of the tumor. Size, appearance on all sequences, enhancement, cystic and solid portions should be known and compared to the postoperative images

Take-Home Messages

- Early postoperative (within 48 h after surgery) MRI should be obtained in all brain tumor patients who had surgical resection
- Comparison of all sequences and slices of the preoperative and postoperative images is necessary to evaluate residue tumor and other findings related to surgery
- On follow-up MRIs, the size of the residue tumor may increase (progress) and may also show increase in tumor grade (upgrade)
- If a non-enhancing tumor begins to show enhancement on follow-up, this is highly suggestive for tumor upgrade

Further Reading

- Barbagallo GM, Jenkinson MD, Brodbelt AR. 'Recurrent' glioblastoma multiforme, when should we reoperate? Br J Neurosurg. 2008;22:452–5
- Cha S. Update on brain tumor imaging: from anatomy to physiology. AJNR Am J Neuroradiol. 2006;27:475–87