Hybrid PET/MR Imaging of Breast Cancer: Advantages and Pitfalls

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Learning objectives

The purpose of this exhibit is:

1. To understand the advantages and pitfalls of FDG-PET/MR imaging with breast cancer.

2. To determine appropriate management recommendations for the lesions.

Background

Hybrid PET/MR imaging units became available in the diagnosis of breast cancer. We need to know about clinical advantages and pitfalls, so we will explain them based on experiences and showing examples.

Findings and procedure details

A. Indications for PET/MRI

Pre-operative breast cancer	• Whole body staging • Diagnosis of the extent of breast lesions (requires contrast-enhancement) • Interpreting therapeutic responses to neoadjuvant chemotherapy
Post-operative breast cancer	• Restaging • When recurrence is suspected • Interpreting therapeutic responses to chemotherapy

In breast cancer, the following indications are conceivable for each of MRI and PET.

• **Breast MRI** (requires contrast-enhancement)

- Cancer screening with a high-risk population.

- Pre-operative breast MRI - Its routine use remains controversial.

- Interpreting therapeutic responses to neoadjuvant chemotherapy.

• **Breast PET**

- Although it might be a precise examination, there may be no indication only with breast PET.

• **Body MRI**

- Investigation of the suspected or symptomatic site.

• **Whole Body PET**

- Screening for cancer with PET - Not recommended for breast cancer.

- Post-operative breast cancer - Recommended for patients with positive clinical test findings

- Pre-operative staging - Not recommended for stage I or II initial primary breast cancer presenting with no symptoms or findings indicative of distant metastasis.

18F-FDG PET/CT and PET/MRI are reported to be performed equally well in Cancer. With PET/MRI, the combination of PET and MRI makes it possible to diagnose the extent of disease in the breast and search for metastasis of the whole body at once, and to confirm the lesion details in MRI.

B. Scanning technique and theory

• **PET attenuation correction is based on MRI.**

PET/CT uses CT images for attenuation correction. PET/MRI uses segmentation method using MRI image and there is no additional radiation exposure. One of the major problems of this methods is that the cortical bone is classified as soft tissue. And when body fat is small, it may recognize soft tissue and adipose tissue in reverse. Solutions are being made with new segmentation methods. The values of SUV are reported to be 20 - 40 % lower than PET/CT by the attenuation correction not recognizing bones.

• **PET scanning time, simultaneous scan.**

Unlike PET/CT, MR images are obtained during simultaneous PET acquisition with PET/MRI. The simultaneous PET scan enables the truly same position images and enables the accurate measurement of PET and MRI.

During the PET scan, some MRI sequences are obtained such as T1-weighted images and T2-weighted images. In our institution, T1-weighted VIBE, axial T2-weighted half-Fourier single-shot turbo spin-echo(HASTE) sequences, and axial diffusion-weighted

imaging(DWI; b = 0, b = 800) were obtained during simultaneous PET acquisition. Four to five PET bed positions were usually required, and the emission time per bed is 4 min.

The breast PET/MRI comprised a breast PET scan of one-bed position and MRI including dynamic contrast enhancement with dedicated breast coil at a prone position. Scan time is 15 min at our institution.

C. Whole-body PET/MRI

• **Staging**

The indication of using PET/MRI for staging purposes is limited, but it is very powerful with the simultaneous imaging of the whole body MRI and PET since both the screening and the precise examination are possible at one time.

Breast DCE scan with a prone position is superior for evaluation of the breast lesion, but it is possible to determine the lesion in the supine position which is close to the surgical position.

• **Lymph nodes** (Fig. 1 on page 8 , Fig. 2 on page 9 , Fig. 3 on page 10)

Both MRI and PET have limited lymph node metastasis retrieval ability, which is considered to be equivalent to PET/CT. Although MRI shows morphological information and size, the spatial resolution is inferior to CT.

The quantitative evaluation with DWI is expected, but it is difficult to differentiate with DWI because the normal lymph nodes also present high signal.

About the diagnostic ability of axillary lymph node, the sensitivity is low and specificity is high in PET. There is no clear cutoff with SUV. Metastatic lymph node often shows no obvious FDG uptake. On the other hand, lymph nodes with distinct FDG uptake are almost convinced of metastases.

There is a possibility that FDG uptake is low in lymph nodes due to the attenuation correction methods. Therefore, an investigation will be needed to verify how useful the assessment combined with the prone position imaging.

Fig. 1: Left breast cancer with pathologically proven axillary lymph node metastasis (negative on PET / MRI). A. T1WI with fat saturation, B. T2WI, C. DWI, D. PET-T2WI fusion, E. PET, F. PET (MIP). In PET (D to F), no abnormal FDG accumulation was seen with the axillary lymph node, and neither lymph node swelling nor the obvious difference between the contralateral axilla was observed in MRI (A to C). This case

was considered clinically N0, thus sentinel lymph node biopsy was performed, and lymph node metastasis was confirmed pathologically.
References: Sagara Perth Avenue Clinic, Social medical corporation Hakuaikai - Kagoshima/JP

Fig. 2: Left breast cancer with axillary lymph node metastasis (positive on PET). A. T1WI with fat saturation, B. T2WI, C. DWI, D. PET-T2WI fusion, E. PET, F. PET (MIP). Abnormal FDG uptake was seen with the axillary lymph node in PET (D to F), and MRI also showed the obvious signal increase on DWI (C) and slight swelling on T1WI (A) and T2WI (B). This case was considered clinically N1, and lymph node metastasis was confirmed by axillary lymph node dissection.
References: Sagara Perth Avenue Clinic, Social medical corporation Hakuaikai - Kagoshima/JP

Fig. 3: Left breast cancer with axillary lymph node metastasis (positive on PET). A. T1WI post Gd, B. PET, C. PET-T1WI fusion, D. PET (MIP) The same case with Fig. 2. Even with breast dedicated coil, the left axillary lymph node showed obvious FDG uptake.
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• **Detection of distant metastases**

Along with the whole body PET examination, it can be evaluated as whole-body MRI including DWI.

In the diagnosis of **bone** metastasis, the diagnostic ability is improved by the diagnosis not only from FDG accumulation but also from signal/ morphology of MRI. In addition, when a metastasis to the vertebral body is suspected, it is also possible to add sagittal MRI scans. However, it is a matter how much time it takes at one study (Fig. 4 on page 11).

Fig. 4: Left breast cancer with multiple bone metastases. Both abnormal FDG uptake (A) and DWI high signal (B) were seen in the multiple bones. Lesions in the PET and MRI were well fitted in the fusion image (D). Multiple bone metastasis lesions are depicted in low signals in T1WI MPR images (C). In T2WI (E), bone metastasis lesion was expressed with low signal, no tumor beyond the bone or spinal canal stenosis was seen. It is thought that it corresponds to osteosclerotic bone metastasis.
References: Sagara Perth Avenue Clinic, Social medical corporation Hakuaikai - Kagoshima/JP

Liver metastasis can also be diagnosed with both PET and MRI. With less misregistration between the PET and MRI, small lesions may be more clearly visualized. Due to physiological accumulation, it is sometimes difficult to detect small lesions with PET alone. But small lesions can be further identified by matching MRI such as DWI (Fig. 5 on page 12).

Fig. 5: Right breast cancer with multiple liver, bone, and lymph node metastases. Both MRI (A: T1WI, B: T2WI, C: DWI) and PET (D: PET-T2WI Fusion, E: PET, F: PET (MIP)) depicted multiple liver metastases. Liver metastases were obvious in PET (E). Moreover, DWI depicted another small liver metastases (C).
References: Sagara Perth Avenue Clinic, Social medical corporation Hakuaikai - Kagoshima/JP

For **lung** metastasis, both PET and MRI have limitations in the visualization of pulmonary nodules, and their detection capability is lower than CT. It is difficult to depict small nodules with general MRI sequences (Fig. 6 on page 13).

Fig. 6: Multiple lung metastases. A. T1WI with fat saturation, B. T2WI, C. DWI, D. PET-T2WI fusion, E. PET, F. CT. CT (F) identified multiple pulmonary nodules, but it was hard to point out them with PET or MRI.
References: Sagara Perth Avenue Clinic, Social medical corporation Hakuaikai - Kagoshima/JP

One of the disadvantages of PET/MRI is that it may be difficult to recognize the anatomical parts in some cases. Sometimes it is difficult to distinguish whether the site of the lesion is the rib or the pleura, or the number of the ribs and the vertebral bodies may be difficult to understand only by the axial images.

• Treatment response evaluation

PET and MRI may be used for monitoring therapeutic effects. It seems to be useful because PET can show the change in metabolism precedes the change in size. MRI is also expected with qualitative response evaluation using such as DWI.

It is not so clear that the proper scan timing and the appropriate treatment change timing. It can be considered that using PET/MRI for the first time and use MRI for follow-up study.

D. PET / DCE breast MRI fusion

• What can be seen with PET and the contrast-enhanced images?

The significance of PET diagnosis of breast cancer is still uncertain, but comparisons with PET and MRI had been often done separately. It is possible to investigate the accurate parameters of PET and MRI by the accumulation by the simultaneous scan. It is also possible to know the state in each of the prone position and the supine position.

• What can be seen with PET and DWI?

FDG-PET and DWI are both functional modalities that indirectly represent the biological characteristics of breast cancer. Breast cancer has an intratumoral heterogeneity, thus a needle biopsy shows only the information of a part of the tumor. Combining these functional image findings with morphological information is expected for prediction of information including subtype and for the usage as a biomarker.

- About **invasive cancer**, FDG uptake is often low with **luminal A** type breast cancer (Fig. 7 on page 14). On the other hand, FDG uptake tends to be high with triple negative breast cancer (**TNBC**) (Fig. 8 on page 15), **HRE2 positive** breast cancer (Fig. 9 on page 16), and luminal B type breast cancer.

Fig. 7: Right breast cancers (Luminal A type and DCIS) A: T1WI (post-contrast MIP), B, C: PET-MRI Fusion, D: PET (MIP) Pathologically confirmed invasive cancer (blue arrow) and noninvasive cancer (yellow arrow). Fusion images showed contrast enhancement and weak FDG uptake on each lesion exactly due to the simultaneous scanning.
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Fig. 8: Righ breast cancer (TNBC: triple negative breast cancer). A: T1WI (post-contrast MIP), B: T1WI (post-contrast), C: DWI, D: PET-MRI Fusion, E: PET, D: PET (MIP) Strong FDG uptake is seen consistent with circumscribed round mass on the MRI. DCE showed a fast-washout pattern with intratumoral necrosis. These are characteristic findings of TNBC.
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Fig. 9: HER 2 positive breast cancer A: T1WI (post-contrast MIP), B: PET, C: PET-MRI Fusion, D: PET (MIP) Large tumor and multiple lesions are depicted on MRI and PET. Heterogeneous strong FDG uptake was seen on the tumor.
References: Sagara Perth Avenue Clinic, Social medical corporation Hakuaikai - Kagoshima/JP

- **Mucinous carcinoma** often shows a characteristic T2WI high signal, persistent type enhancement in DCE study, and low FDG uptake in PET (Fig. 10 on page 17).

Fig. 10: Mucinous carcinoma. A: PET (MIP), B: T1WI (post-contrast MIP), C: T2WI, D: Fusion (PET and T1WI post-contrast) An Irregular shape, well-defined tumor exhibited showed high signal with the T2 weighted image. On dynamic-contrast enhanced study, persistent type enhancement was shown. PET showed mild FDG uptake.
References: Sagara Perth Avenue Clinic, Social medical corporation Hakuaikai - Kagoshima/JP

- **DCIS** often exhibits non-mass enhancement especially with segmental enhancement, clumped pattern, and clustered ring enhancement on MRI. FDG uptake is often low in PET but sometimes shows moderate to high SUV (Fig. 11 on page 18 , Fig. 12 on page).

Fig. 11: DCIS. A: PET (whole body MIP), B, C: Fusion (PET and post-contrast T1WI), D: T1WI (post-contrast MIP) There was low FDG uptake in PET is weak, but the lesion can be confirmed by fusion image with contrast MRI. MRI showed focal non-mass enhancement with a clumped pattern.
References: Sagara Perth Avenue Clinic, Social medical corporation Hakuaikai - Kagoshima/JP

Fig. 12: DCIS. A: PET (MIP) , B, C: T1WI (post-contrast MIP), D: Fusion (PET and post-contrast T1WI) FDG uptake in PET was weak, but weak accumulation site could be confirmed by fusion image with contrast MRI. MRI exhibited segmental non-mass enhancement with a clumped pattern.
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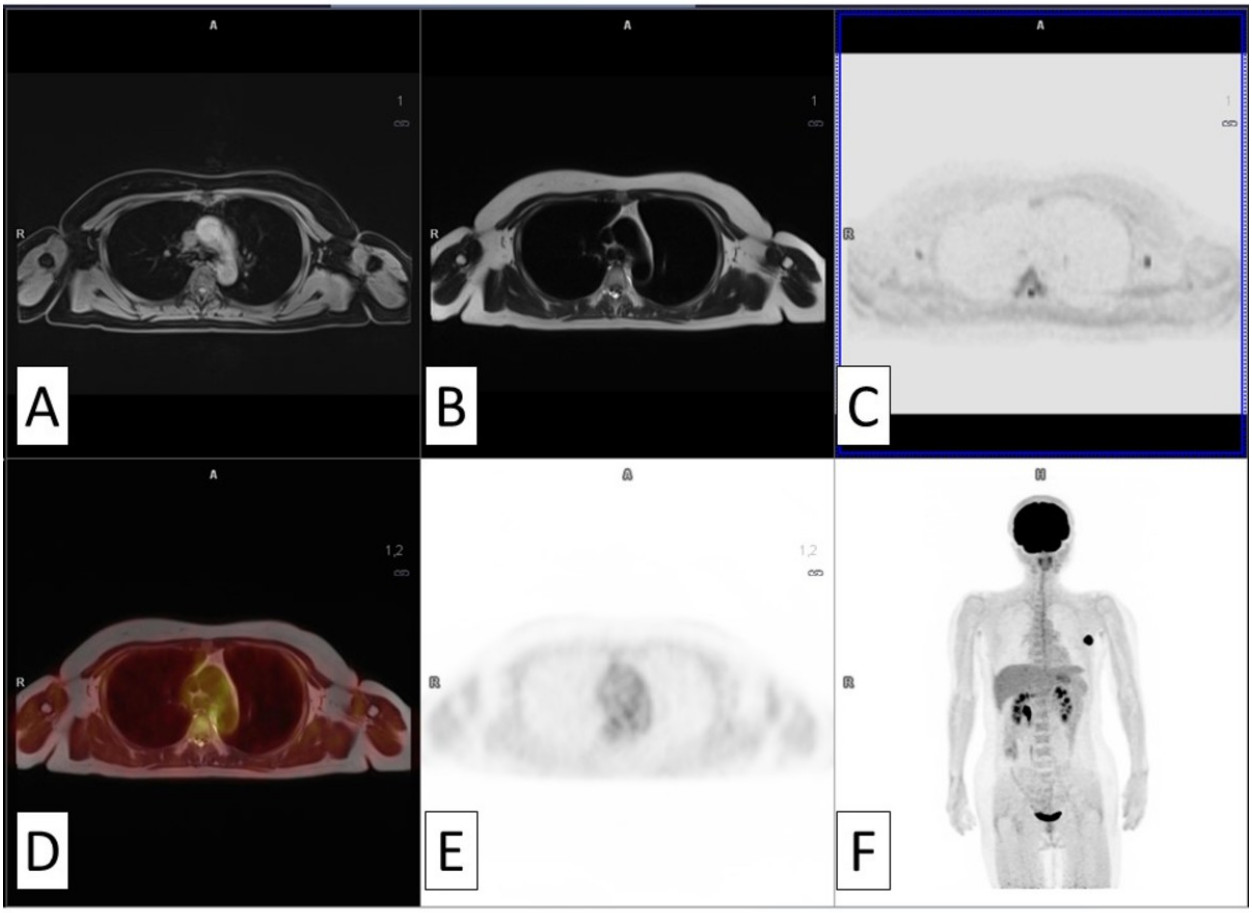
Diagnosis by combining morphology, information such as DCE, DWI, and SUV may lead to a precise diagnosis.

Images for this section:



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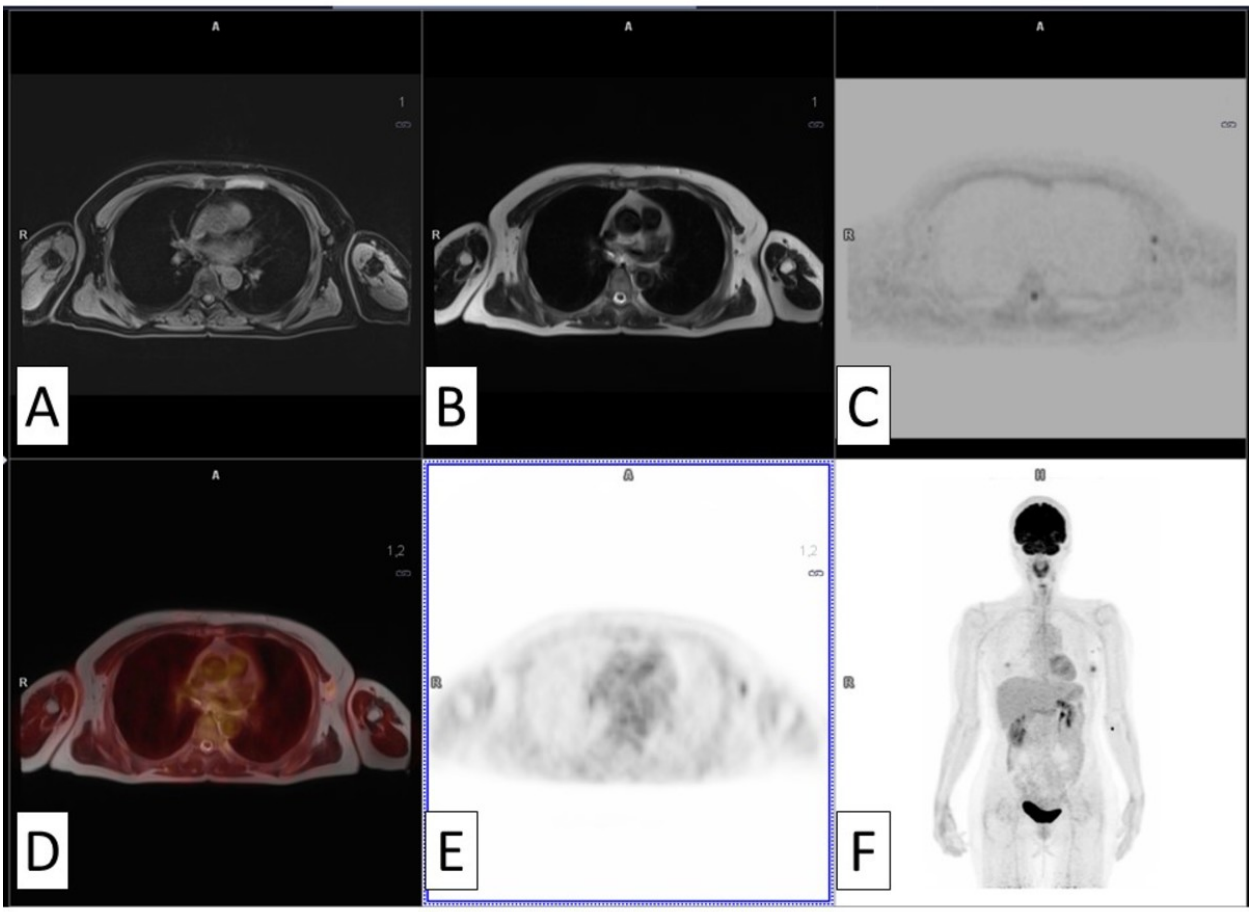

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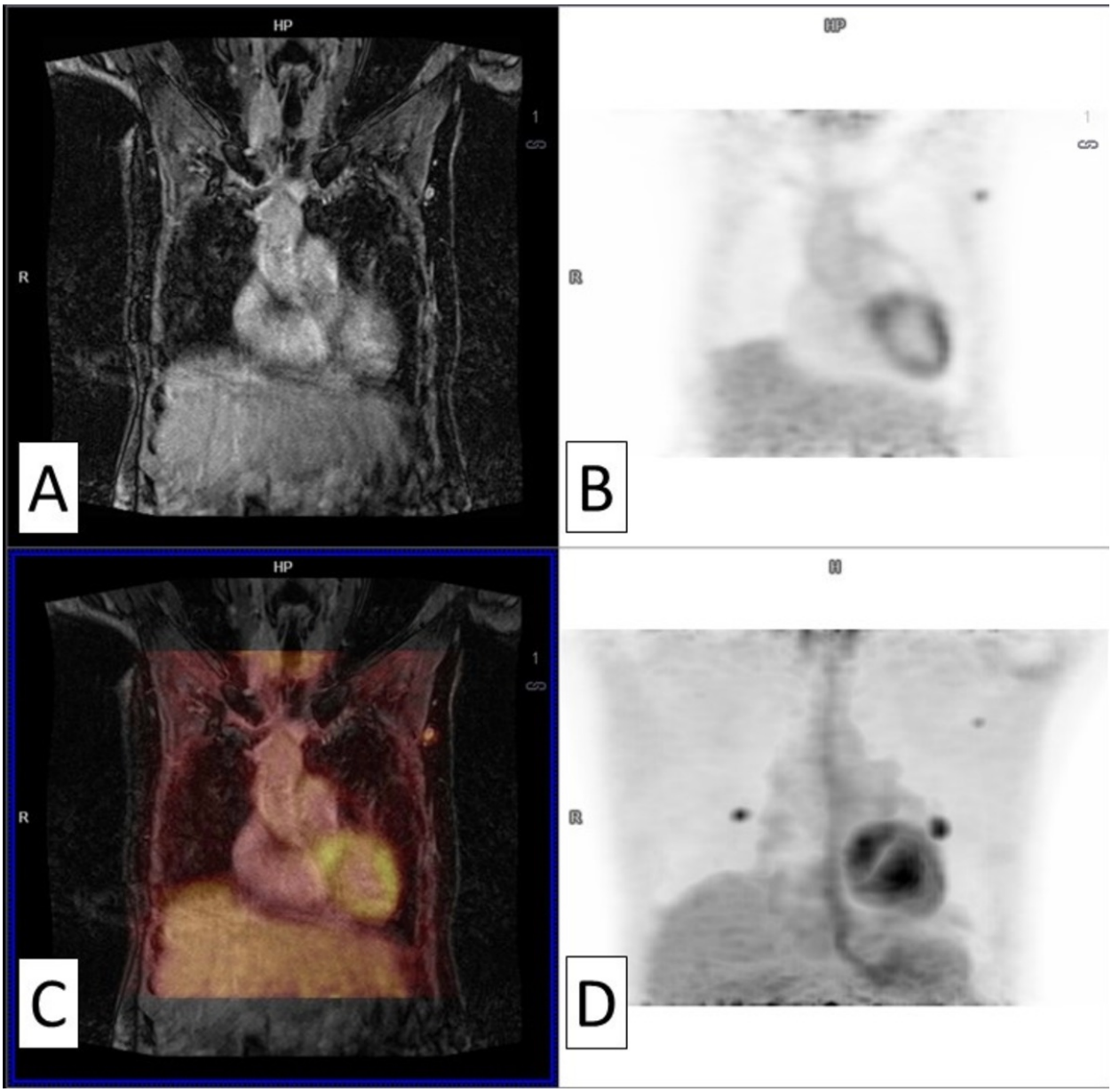

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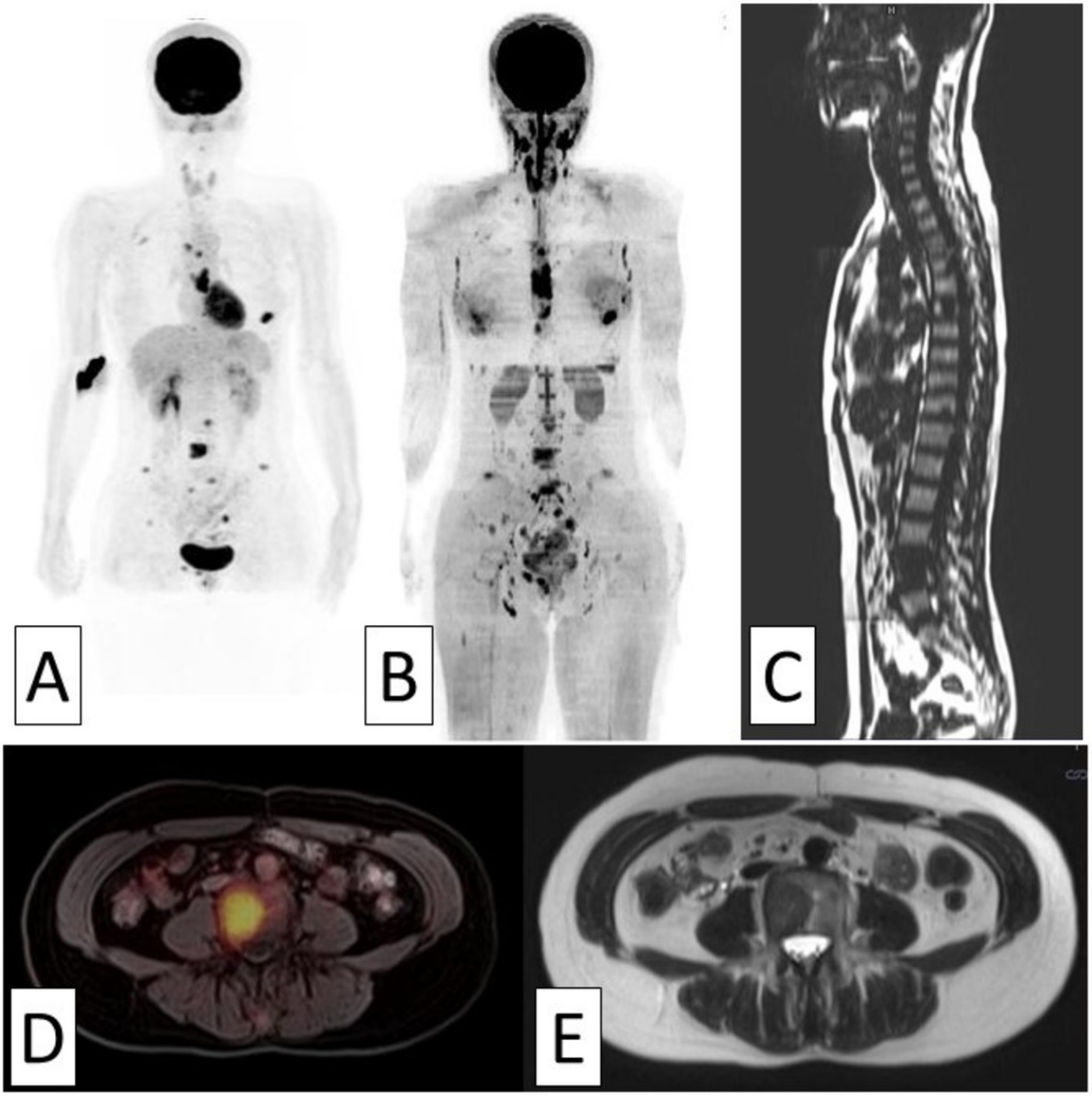

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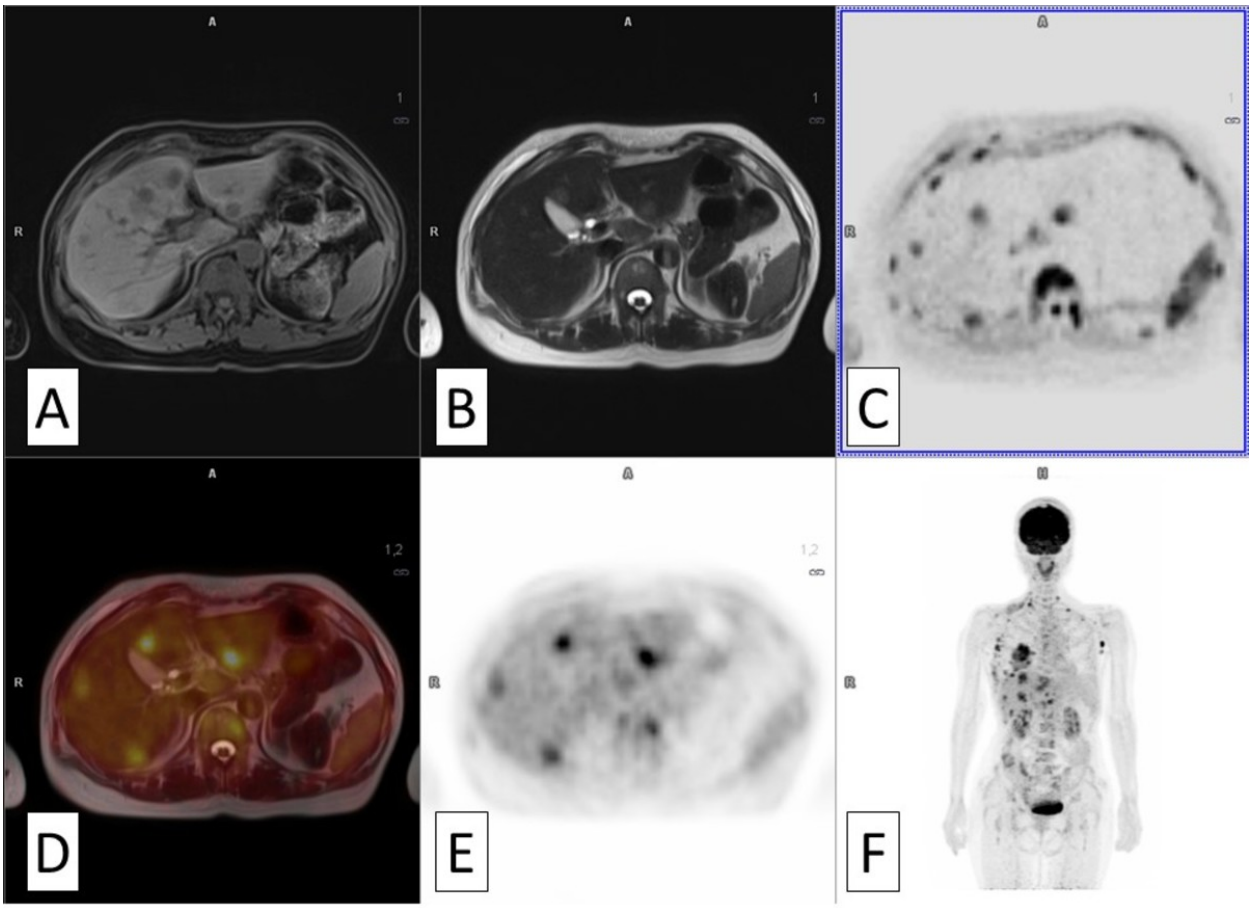

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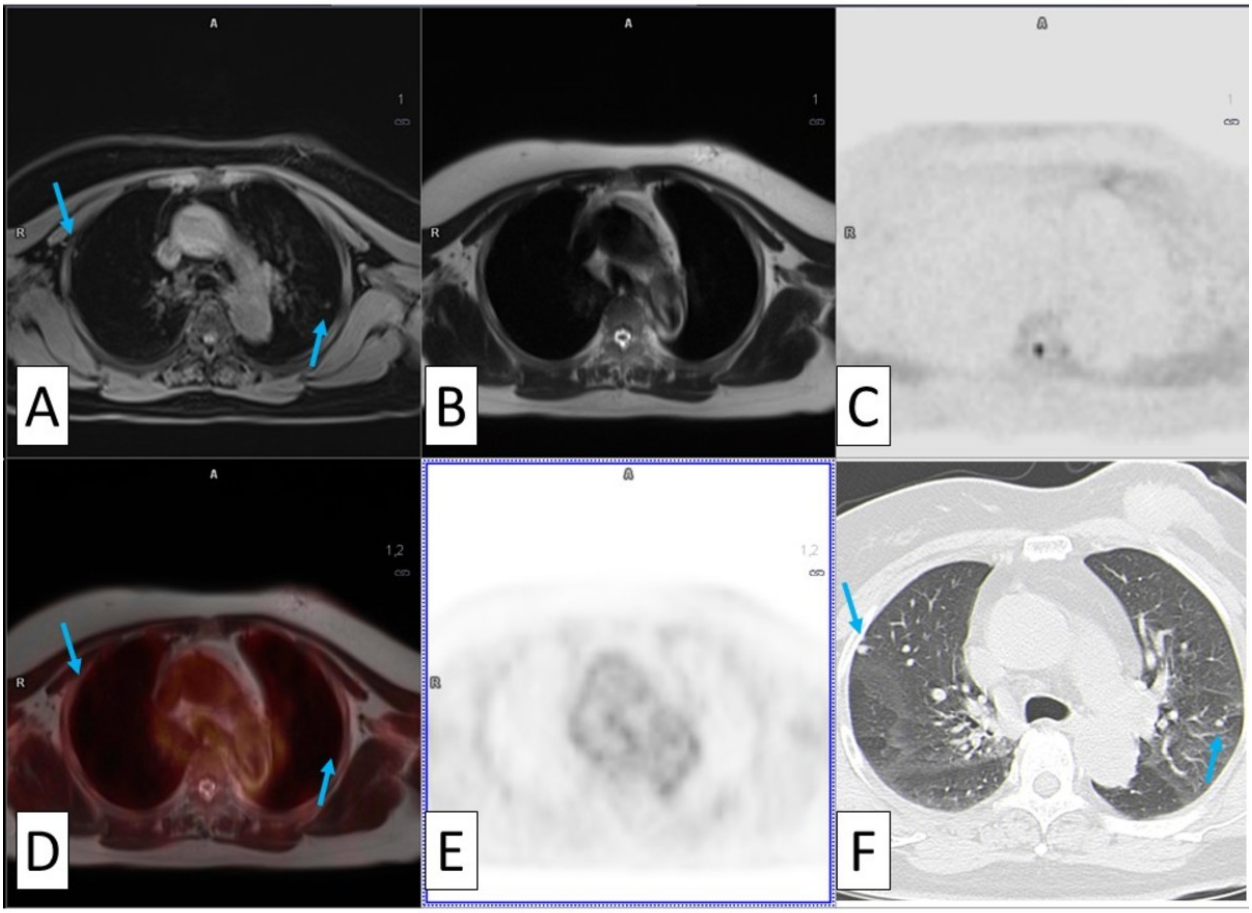

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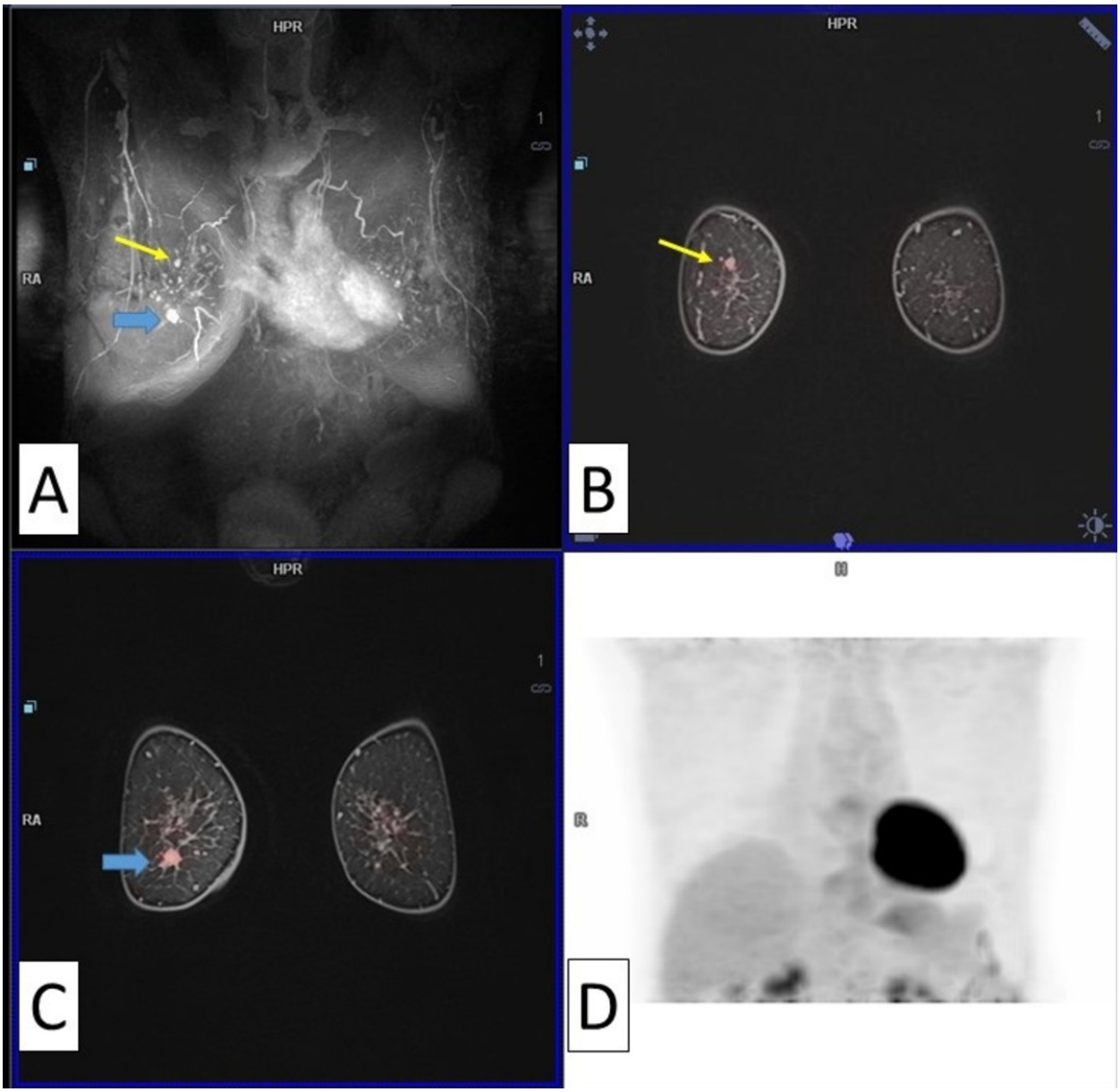

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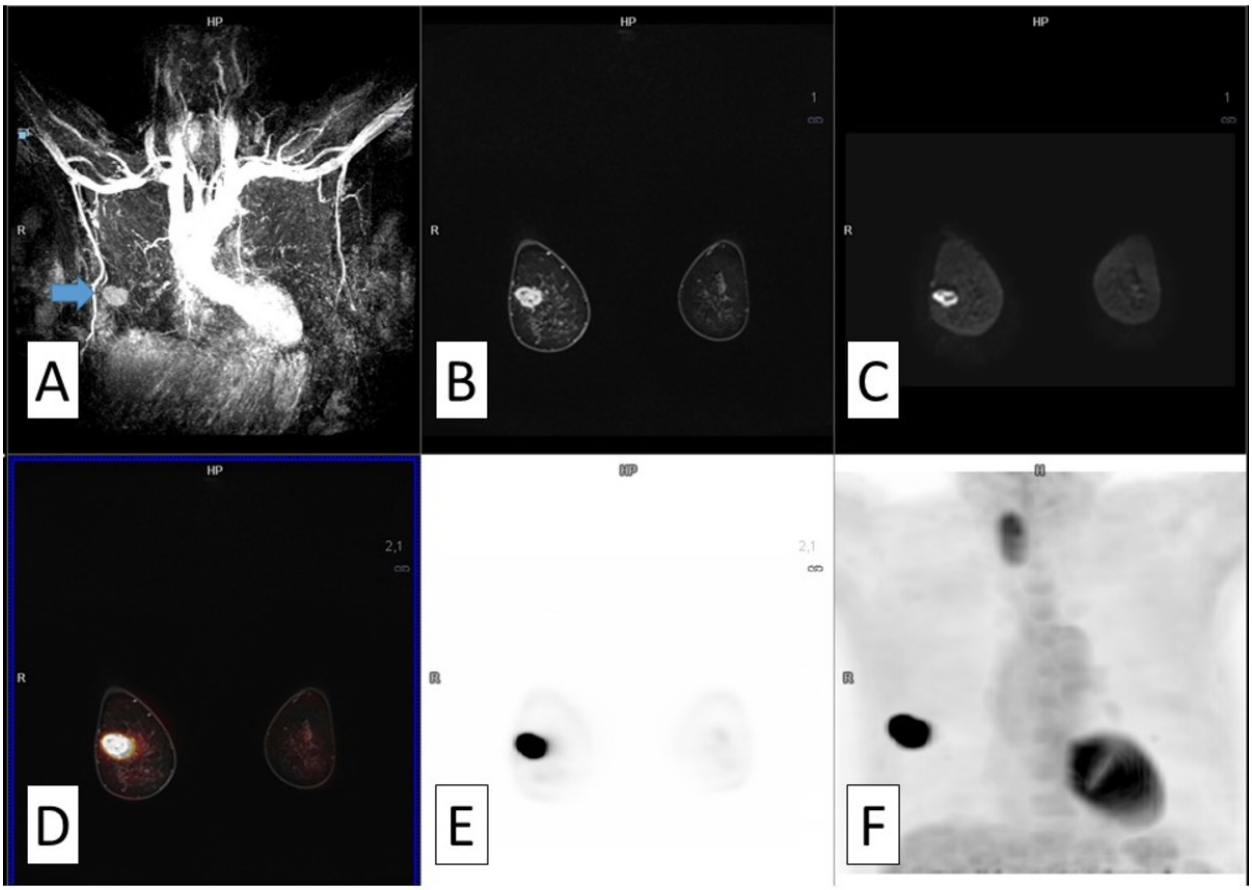

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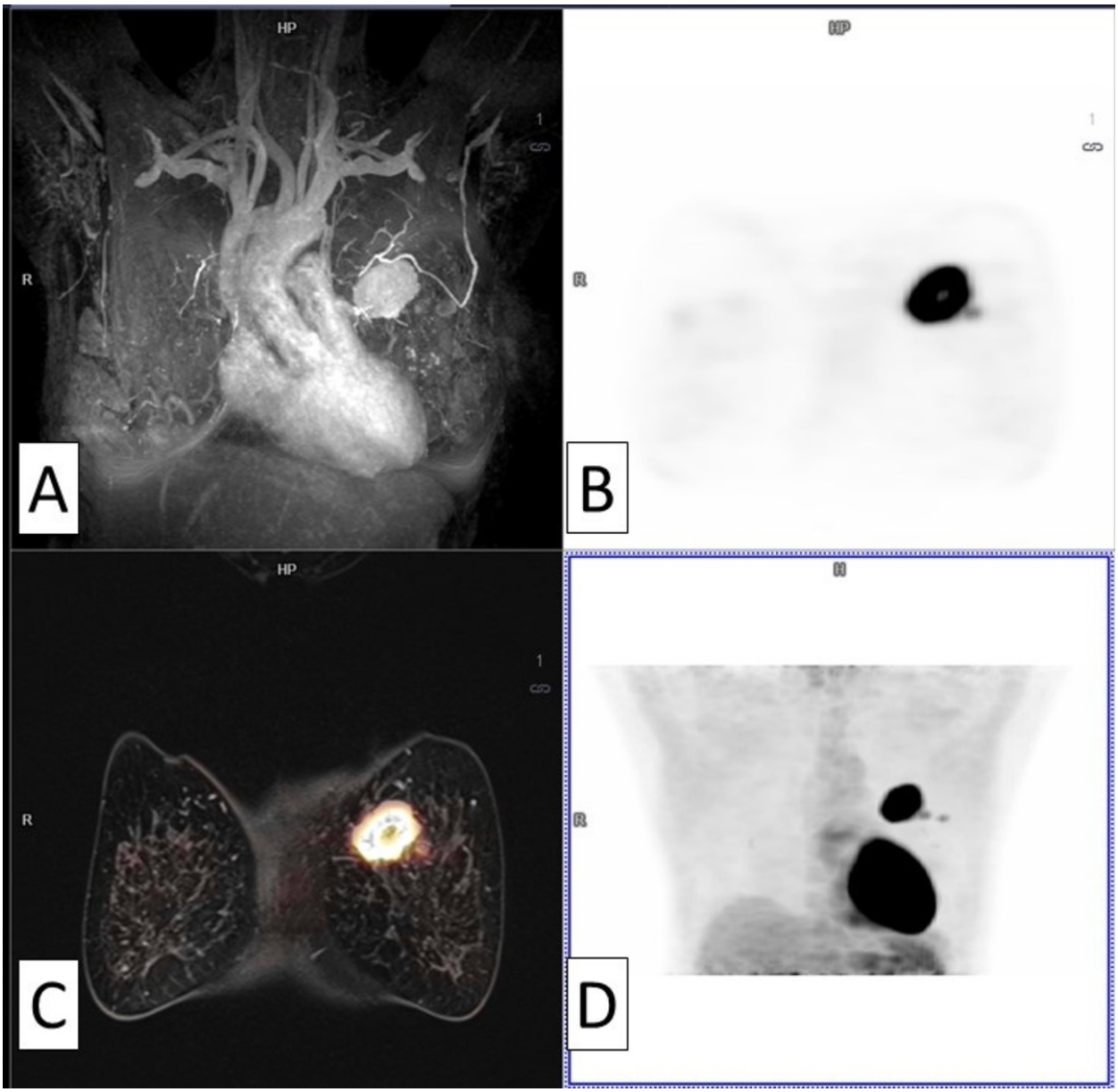

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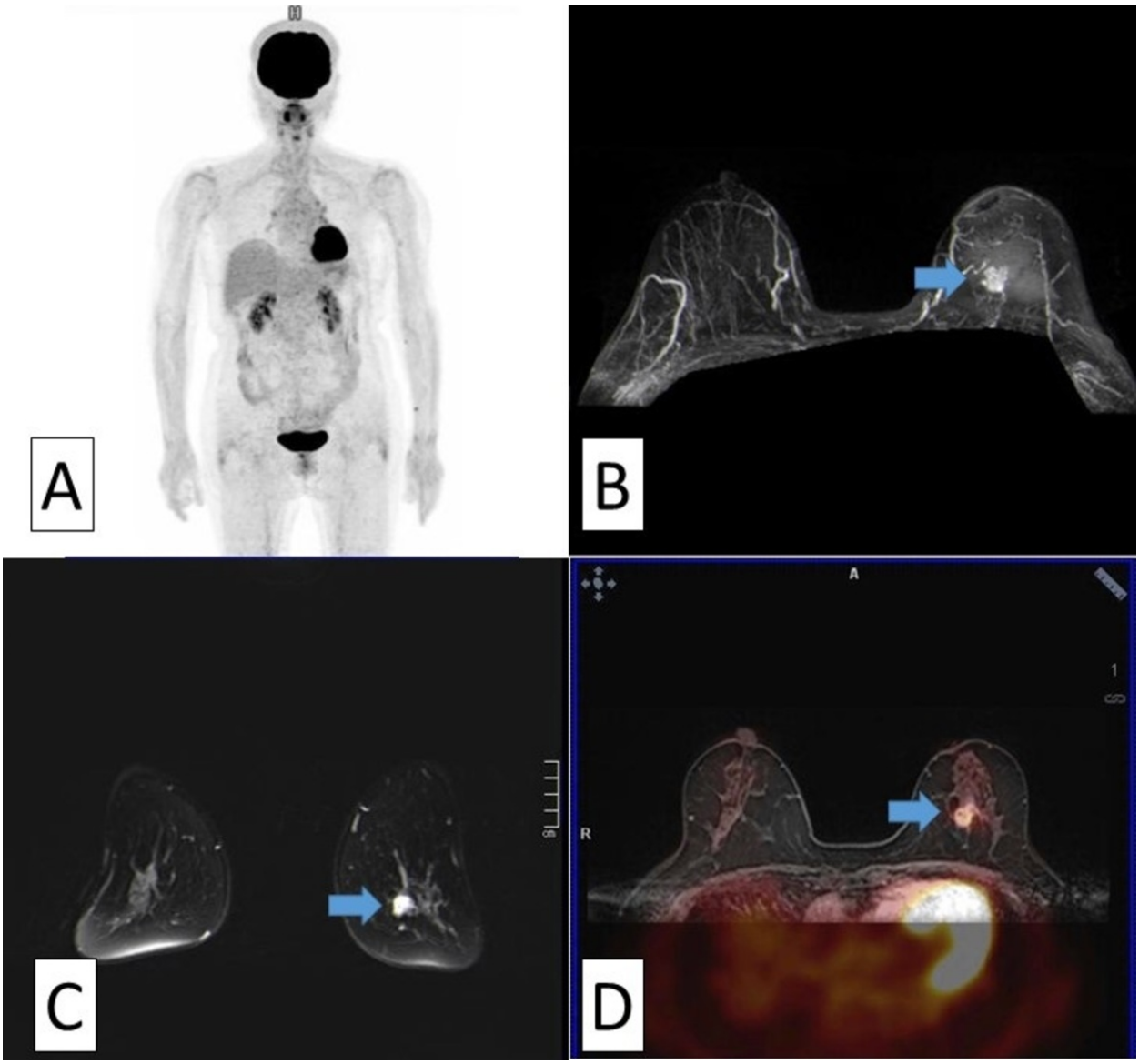

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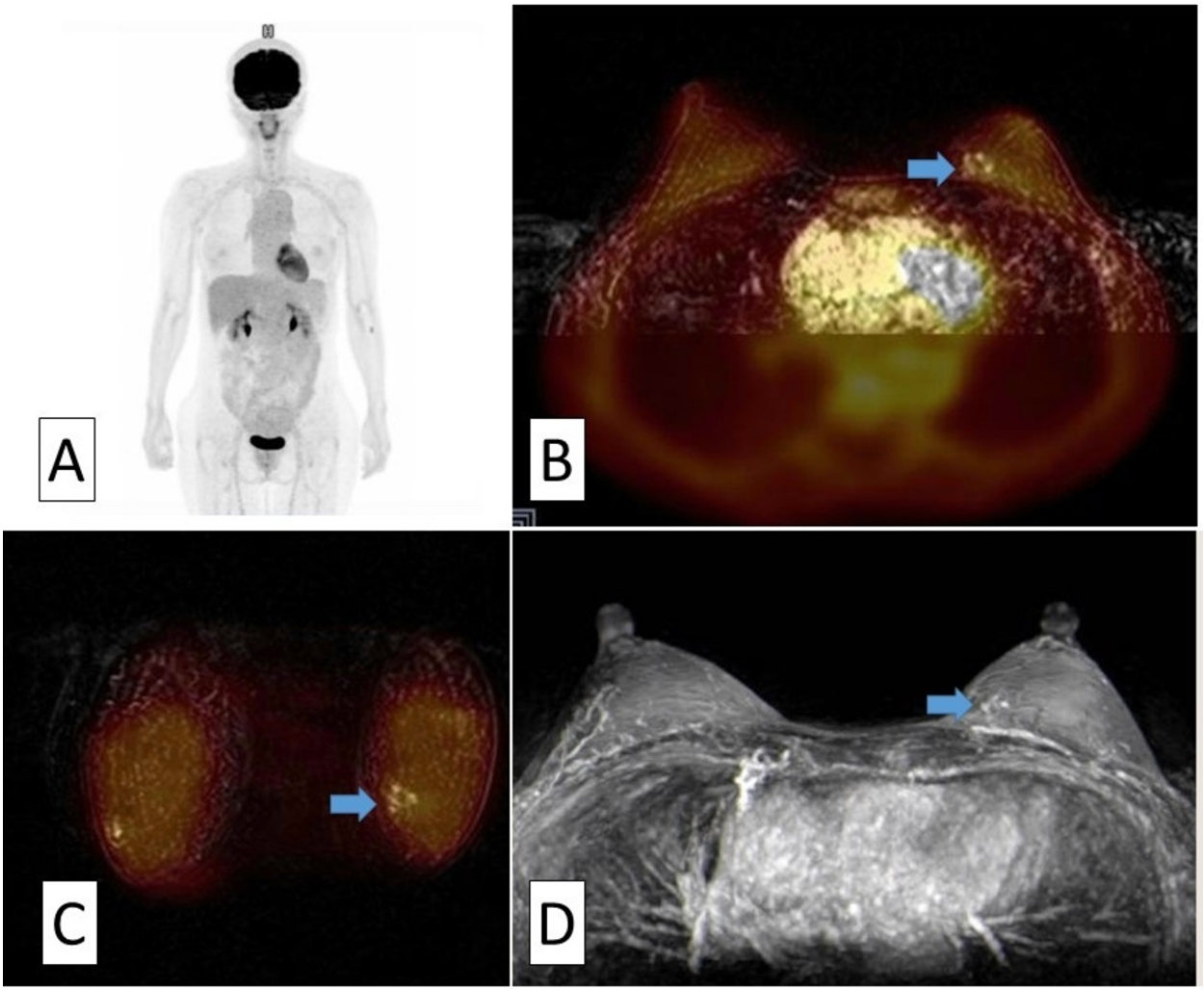

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Conclusion

Although PET / MRI is clinically useful for breast cancer, it also has pitfalls. It is also important to apply this technology and diagnostic findings to whole-body MRI and breast MRI.

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