**Multi-volume Fusion Imaging of MR Ductography and MR Mammography for Patients with Nipple Discharge**

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Because nipple discharge is caused by carcinoma as well as benign disease, identification of intraductal abnormalities with ductography is important. Ductography is an invasive mammographic examination in which contrast material is injected directly into the duct. Failure to cannulate or extravasation may occur. Ductography shows evidence of lesions, such as filling defects, duct obstruction, or wall irregularity, but it does not reveal the lesion itself. Furthermore, ductography produces a two-dimensional image, so it does not show the shape of the dilated duct or the precise location of the intraductal lesion in the breast.

We applied three-dimensional (3D) heavily T2-weighted imaging with fat suppression of the breast to produce MR ductography. The dilated ducts are seen in 3D as tubular structures with high signal, and intraductal abnormalities are seen as signal defects. Furthermore, MR ductography can show an obstructed duct that cannot be seen on ductography. We also performed 3D breast MRI with the intravenous infusion of contrast material to demonstrate the lesion itself. Finally, we fused these 2 volume images into a single 3D fused image that not only shows the existence of intraductal abnormality, but reveals the shape, size, and extent of lesion, allowing us to understand easily the relationship between the ducts with dilation and any intraductal lesions in the breast.

We herein introduce and describe this noninvasive method and discuss various factors related to its diagnostic use.

**Keywords:** breast, MRI, nipple discharge, ductography, fusion

**Background**

Nipple discharge is caused by carcinoma as well as benign disorders, so the ability to identify intraductal abnormalities with ductography (also called galactography) is important.1 Ductography is an invasive mammographic examination in which contrast material is injected directly into the draining duct. Failure to cannulate, extravasation, or inflammation from the examination may occur. Ductography reveals evidence of lesions as intraductal filling defects, complete duct obstruction, or wall irregularity,1–3 but it does not reveal the lesion itself.

We employed heavily T2-weighted imaging with fat suppression of the breast for 3-dimensional (3D) MR ductography. As with conventional ductography, with the 3D MR imaging, dilated ducts are imaged as tubular structures with high signal, and abnormalities are seen as signal defects in the dilated ducts. However, 3D MR ductography shows the 3D shape of the dilated ducts and the precise location of the intraductal lesion in the breast and is not invasive. Although conventional ductography cannot show the distal portion of abnormal duct when contrast material cannot enter because of obstruction by intraductal lesions, MR ductography can show the distal portion of an obstruction. We also applied breast MR imaging (MR mammography) by intravenously injecting contrast material to demonstrate the lesion itself as enhancing. Finally, we fused the images from MR ductography and MR mammography, creating an image that demonstrates the existence of intraductal abnormality and reveals the shape, size and extent of lesions. This 3D fusion image enables us to understand easily the relationship of the dilated ducts with a specific location in the breast.
ducts and intraductal lesion in the breast.

We introduce this noninvasive diagnostic method for patients with nipple discharge and discuss some characteristics of this method.

**Methods**

All MR imaging was performed with the patients in the prone position on a 1.5T magnet (Signa system; GE Yokogawa Medical Systems, Japan). Examinations were performed unilaterally using a phased-array breast coil. The imaging parameters of MR ductography and MR mammography were as follows: **MR ductography.** MR ductography was performed with fat-saturated, heavily T2-weighted, fast spin echo sequence (repetition time/echo time \(\text{TR/TE} = 7000/153.3\); 30 slices obtained in 231 s); field of view (FOV) = 16 cm; matrix = 256 × 256; number of excitations (NEX) = 2; and section thickness = 3.0 mm with no intersection gaps; or

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**Fig. 1.**

*a*: Mammography shows no abnormality.

*b*: Ultrasonography demonstrates a dilated duct and an intraductal lesion (arrow).

*c*: Ductography reveals a dilated duct and an intraductal filling defect (arrow).

*d*: MR ductography also shows a dilated duct and an intraductal lesion (arrow).

*e*: MR mammography reveals a tiny enhanced lesion (arrow).

*f*: A fused image from MR ductography and MR mammography shows a dilated duct (red) and intraductal lesion (green) in one image.
Fig. 2.

a: Ultrasonography shows the dilated duct and the intraductal tumor (arrow).
b: MR ductography (maximum projection image = MIP) shows the dilated duct and the intraductal abnormality as a signal defect (arrow).
c: MR mammography (MIP) shows the intraductal abnormality as an enhanced lesion (arrow).
d,e: Multi-volume fused image from 3D MR ductography and 3D MR mammography shows a dilated duct (green) and an intraductal lesion (red) in one image.
f–h: Follow-up MR ductography in (f) 2003, (g) 2004, and (h) 2005 shows that the dilated duct and intraductal lesion seem to have no significant interval change.
Fig. 3.

a: Ductography shows dilated duct and intraductal abnormality as a filling defect (arrow).

b: MR ductography (maximum projection image = MIP) shows the dilated duct and the intraductal abnormality as a signal defect (arrow).

c: MR mammography shows the intraductal abnormality as an enhanced lesion (arrow).

d: Multi-volume fusion of 3D MR ductography and 3D MR mammography shows the 3D shape of the dilated duct (green) and the precise location of the intraductal lesion (orange) in the breast in one image.

Contrast material (meeglumine gadopentate, 15 mL; Magnescope, Tanabe, Japan) was intravenously injected followed by a saline flush; image acquisition was initiated 24 s after injection.

Image processing

Three-dimensional images, maximum projection images (MIP) and multi-volume fusion images of MR ductography and MR mammography were created using a Virtual Place Advance work station (Office AZE, Ltd./Medical Imaging Laboratory, 

Magnetic Resonance in Medical Sciences
Fig. 4.
a: Ductography shows one obstructed duct and no other abnormality.
b: MR ductography (maximum projection image = MIP) shows one dilated duct (allow) and multiple cystic dilated ducts (allow head) that are not seen on ductography.

Cases

Case 1. A woman in her seventies had serous nipple discharge with cytology of Class II. Mammography (Fig. 1a) showed no abnormality. Ultrasound (Fig. 1b) demonstrated a dilated duct and intraductal lesion (arrow). Ductography (Fig. 1c) and MR ductography (Fig. 1d) revealed a dilated duct and intraductal filling defect (arrow). MR mammography (Fig. 1e) revealed a tiny enhanced lesion (arrow). A fusion of MR ductography and MR mammography images (Fig. 1f) showed a dilated duct (red) and an intraductal lesion (green) in one image.

Case 2. Ultrasoundography of a woman in her fifties with intraductal papilloma showed a dilated duct and intraductal tumor (arrow) (Fig. 2a). MR ductography (MIP) showed a dilated duct and an intraductal abnormality as a signal defect (arrow) (Fig. 2b). MR mammography (MIP) showed the intraductal abnormality as an enhanced lesion (arrow) (Fig. 2c). Multi-volume fusion of 3D MR ductography and 3D MR mammography (Figs. 2d, e) provided a 3D image of the shape of the dilated duct (green) and the precise location of the intraductal lesion (red) in the breast in one image.

MR ductography is noninvasive, so follow-up examination can be easily performed. Figures 2f, g, and h represent the follow-up MR ductography findings of this case from 2003, 2004, and 2005. The dilated duct and intraductal lesion show no significant interval change.

Case 3. Ductography (Fig. 3a) of a woman in her forties with intraductal papilloma showed a dilated duct and an intraductal abnormality as a filling defect (arrow). MR ductography (Fig. 3b) showed the dilated duct and the intraductal abnormality as a signal defect (arrow). MR mammography (Fig. 3c) showed the intraductal abnormality as an enhanced lesion (arrow). Multi-volume fusion of 3D MR ductography and 3D MR mammography (Fig. 3d) revealed the 3D shape of the dilated duct (green) and the precise location of the intraductal lesion (orange) in the breast in one image.

Case 4. MR ductography can show the distal site of the duct obstructed by intraductal lesion, and ductography cannot. Ductography in a woman in her twenties with intraductal papillomas showed an obstructed duct but no other abnormality (Fig. 4a). MR ductography showed one dilated duct (allow) and multiple cystic dilated ducts (allow head) that were not seen on conventional ductography (Fig. 4b).

Case 5. In a woman with bloody discharge and pathological diagnosis of invasive ductal carcinoma, no dilated duct was seen on MR ductography, but precontrast MR mammography (Figs. 5a,b)
showed a dilated duct as a high-signal structure. Post-contrast MR mammography (Fig. 5c) showed invasive ductal carcinoma as enhanced lesions. Multi-volume fusion of precontrast 3D MR mammography and post-contrast 3D MR mammography (Fig. 5d,e) showed dilated ducts (green) surrounded by enhanced invasive ductal carcinoma (red).

Discussion

Nipple discharge is a relatively common symptom. Most nipple discharges are physiological and not associated with underlying benign or malignant breast neoplasm. Pathological nipple discharge is defined as spontaneous secretion from the breast in the absence of a physiological condition, such as pregnancy or lactation, generally unilateral, emanating from one duct orifice, and appearing clear, serous, pink, serosanguinous, or bloody. The most common causes are benign conditions, such as intraductal papillomas. However, another uncommon but important cause of pathological discharge is breast cancer, with an incidence of from 5 to 21%. Therefore, the identification of intraductal lesions in patients with pathological nipple discharge is important.

The diagnostic imaging methods for patients with pathological nipple discharge are usually mammography, ductography, and, more recently, ultrasonography. However, mammography often fails to reveal lesions because they are usually very small, contain no calcifications, and may be completely intraductal. Ultrasonography may be sensitive for detecting intraductal lesions when performed by experienced sonologists, but it is rarely helpful in establishing the cause of nipple discharge in standard practice. Ductography has been advocated as a method for lesion identification in patients with nipple...
Multi-volume Fusion Image of MR Ductography

Ductography is used for mammographic examination after retrograde filling of lactiferous ducts with contrast material and is, therefore, invasive. Ductography is perceived to be difficult and time-consuming to perform and painful for the patient. As a result, its use is limited. Conventional ductography is technically inadequate in approximately 10% of patients with pathological nipple discharge. The discharge must be present on the day of ductography so that a cannula may be placed in the appropriate duct. Cannula placement in the duct or injection of the contrast material beyond an obstructing lesion is not always successful. Furthermore, an overinjection of contrast medium may lead to perforation and extravasation. Complications include mastitis and hypersensitivity to the iodinated contrast material.

Ductography can be used to identify and locate intraductal lesions. Lesions are observed as either intraductal filling defects or irregular duct walls with or without ductal dilatation or duct obstruction. Ductography does not always show the lesions themselves. Whereas intraductal abnormalities can normally be identified, it is usually impossible to differentiate carcinoma and papilloma.

MR ductography is rarely reported for patients with nipple discharge. A case is reported of MR imaging after administration of contrast medium directly into the discharge duct. An MR imaging technique using a microscopy coil with a diameter of 4.7 cm to show mammary ducts is also reported. Both reports used T_1- and T_2-weighted images for MR ductography.

MR hydrography can noninvasively depict fluid-filled tubular structures. Static or slowly flowing fluids in the body are imaged as structures of high signal intensity and contrast, and bright against a dark background with very low signal intensity. No contrast material, either directly or intravenously administered, is necessary because the hydrographic image contrast derives from heavy T_2-weighting that accentuates the structures that contain fluid with long T_2 relaxation times. This technique has already been used clinically to analyze the bile and pancreatic ducts, the ureter, and the semicircular canals. We applied this technique for MR ductography. The dilated ducts were imaged and observed as tubular structures with high signal on MR ductography. Like conventional ductography, MR ductography reveals the intraductal lesions as signal defects of the ducts.

Investigators have reported that MR imaging of the breast with intravenously injected contrast material has a high sensitivity to invasive breast cancer, ranging from 86% to 100%, with more variable sensitivities for the detection of DCIS, which ranges from 40% to 100%. In addition to the high sensitivity for detecting invasive breast cancer, MR imaging of the breast has the potential for a high sensitivity for detecting intraductal disease and may therefore be useful in examining patients with nipple discharge.

We performed MR ductography on patients with nipple discharge to demonstrate duct abnormalities and intraductal lesions as signal defect of the ducts, and we applied MR mammography with contrast material to reveal the intraductal lesions as enhancing. Furthermore, we fused the images of these two sessions. The fused images demonstrate not only duct abnormalities and intraductal lesions themselves, but in a single image, they clarify the relationship between the duct and intraductal lesions and their size, shape, and extent in the breast. MR ductography is noninvasive, so follow-up examinations can be easily performed.

This method may have some limitations. MR ductography does not always show the pathological duct clearly. Although ductography may show duct abnormalities when the cannula is placed in a duct that is not dilated, MR ductography cannot reveal abnormalities when the duct is not dilated. In some cases, the fluid had high signal intensity on precontrast MR mammography and low signal intensity on heavily T_2-weighted image, suggesting either hemorrhaging or the presence of proteinaceous contents. In a patient with some concentration of blood, it is possible that no dilated duct may be observed on MR ductography or on T_2- or T_1-weighted images.

We did not perform a dynamic study for MR mammography because we thought that spatial resolution was more important than time resolution for detecting small intraductal lesions. This method thus shows intraductal lesions but cannot differentiate between benign and malignant lesions based on the time-intensity curve of enhanced lesions.

**Conclusion**

In a single image, the fused MR ductography and MR mammography image demonstrates duct abnormalities and intraductal lesions themselves and helps clarify the relationship between the duct and intraductal lesions and their size, shape, and extent of lesion in the breast. This image makes it easy to understand the relationship between the dilated ducts and intraductal abnormalities in the breast, and these findings are considered helpful for selecting optimal treatment.
We demonstrated findings from fused images from MR ductography and MR mammography, and we consider this a useful noninvasive diagnostic method for patients with nipple discharge.

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References