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I F Braun, E Chambers, N E Leeds and R D Zimmerman

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The Value of Unenhanced Scans in Differentiating Lesions Producing Ring Enhancement

Ira F. Braun[1]
Evan Chambers[2, 3]
Norman E. Leeds[2]
Robert D. Zimmerman[2]

Ring enhancement with contrast material is a nonspecific computed tomographic finding seen in a variety of lesions, including benign and malignant neoplasms, inflammation, infarction, and hematoma. This lack of specificity is especially troublesome in the differentiation of self-limiting disorders (infarction and hematoma) from progressive processes (tumor or abscess) potentially requiring surgical treatment. To determine whether more specific diagnoses were possible, 115 cases with ring lesions were retrospectively evaluated for the usefulness of precontrast scan features. The presence or absence of a complete ring proved useful. A complete ring on unenhanced scans effectively excluded self-limiting processes; it was seen in none of 18 infarcts or 11 hematomas. A complete ring on unenhanced scans occurred in 37 of 65 neoplasms, and was more common in metastatic disease (2:1) than in gliomas. A complete ring on unenhanced computed tomography was also seen in four of 15 pyogenic abscesses.

The findings of a ring lesion on contrast-enhanced computed tomography (CT) is a striking but nonspecific feature of a variety of lesions, including primary and secondary neoplasms, abscesses, other noninfectious inflammatory disease (e.g., demyelinating disorders), infarcts, and hematomas [1–19]. Ring enhancement may be the result of structural alterations in the brain produced by the inciting lesion (e.g., capsule formation) and reactive hypervascularity at the periphery of the lesion (pathoanatomic changes). This finding may also be caused by pathophysiologic alterations in the surrounding brain parenchyma incited by the lesion, including perivascular leakage of contrast material across a disrupted blood-brain barrier. Considering these structural and functional bases for ring production, we hypothesized that the identification of a ring lesion on noncontrast CT would be more common in those cases in which a pathoanatomic cause for a ring density exists (e.g., neoplasm or abscess) as opposed to entities in which there is a solely pathophysiologic basis for ring enhancement (e.g., infarct). To test this hypothesis, a retrospective analysis of the noncontrast scans in 115 cases showing postcontrast ring enhancement was undertaken.

Materials and Methods

All cases with a suspected or proven primary or metastatic tumor, infectious or noninfectious inflammatory disease (including demyelinating disorders), infarct, and hematoma scanned at Montefiore Hospital and Medical Center during the period from January 1976 to June 1979 were recalled and reviewed by one author (E.C.). From this sizable group, all cases demonstrating postcontrast ring enhancement were selected. All patients were scanned either on the EMI 5005 or the EMI 1005 scanner. The contrast infusion consisted of 300 ml of 30% diatrizoate meglumine (42.3 g iodine) infused rapidly.

Patients were included in the study if the following were available: (1) noncontrast images through the anatomic area of ring enhancement and (2) confirmation by autopsy, surgery, or long-term clinical and CT follow-up. These criteria were met by 115 cases, which were classified by diagnosis (table 1).

The unenhanced scans were then analyzed specifically for the presence of a ring by two authors (I. F. B. and R. D. Z.) without benefit of the corresponding contrast-enhanced scans (table 2). Data obtained were then classified according to the degree and extent of ring visualization on unenhanced scans and the ring characteristics and associated changes in the surrounding parenchyma. The pre- and postcontrast scans were then examined simultaneously to determine if additional, more subtle, noncontrast ring density could be detected using the enhanced scan as a guide. These data were then cataloged with reference to pathologic diagnosis (table 2).

Forty-one cases demonstrated a complete ring on noncontrast scans. Thirty-seven were neoplasms (figs. 1 and 2) and four were chronic pyogenic abscesses (fig. 3). No infarcts or hematomas demonstrated a complete ring without contrast material.

An incomplete or subtle ring on noncontrast scans (figs. 4 and 5) as well as total absence of ring density on the noncontrast scan (fig. 6) were noted in a significant number of cases from all pathologic categories, including self-limiting processes (table 2). Therefore, the presence of an incomplete ring or absence of ring density are nonspecific findings.

Analysis of the neoplasms (table 3) demonstrated that a complete ring on noncontrast scans was most commonly seen in metastatic disease (70%) (fig. 5). It was also seen in two meningiomas and three sarcomas.

Seventeen of 30 cases of metastatic neoplasm had multiple lesions. Not all of the foci showed ring enhancement with contrast material and usually only one ring was seen on noncontrast scans, often the largest.

Gliomas demonstrated a complete ring density on noncontrast scans (fig. 2), without about one-half the frequency (36%) of metastatic disease (70%) (table 3). All cases of glioma that demonstrated a complete noncontrast ring were grades III and IV.

Discussion

Ring enhancement on CT is found in many entities [1–19]. By itself, this finding is of little differential diagnostic value. Our study was rewarded in demonstrating that the noncontrast scans in cases in which ring enhancement is
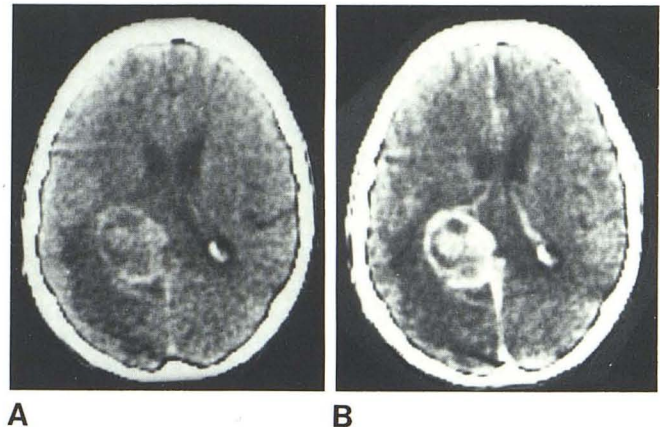

A   **B**

Fig. 1.—Solitary metastasis, complete ring on noncontrast scan. **A**, Unenhanced scan. Complete, well defined ring in right thalamus. Lesion is surrounded by edema. At its center is a nodule of hyperdensity. **B**, After contrast infusion. Intense ring enhancement and enhancement of central nodule.
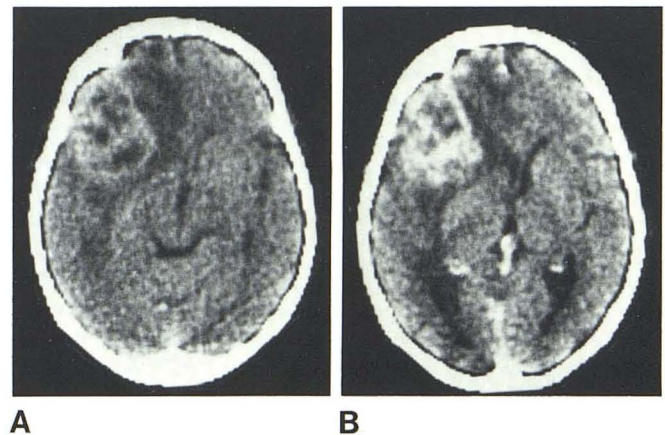

A   **B**

Fig. 2.—Glioma, complete ring on noncontrast scan. **A**, Unenhanced scan. Complete multilocular ring has several areas of necrosis. Edema medially. **B**, After contrast infusion. Irregular ring enhancement. On this slightly higher cut, wedge-shaped configuration of lesion suggests infarction. A complete ring on the unenhanced scan, however, strongly suggests a structural lesion. At surgery a grade IV glioma was encountered.

TABLE 1: Diagnoses of Patients with Ring Enhancement

Diagnosis	No. Cases
Metastatic neoplasm	30
Glioma	30
Miscellaneous tumors	5
Inflammatory lesions	21
Infarcts	18
Hematomas	11
Total	115

Note.—Miscellaneous tumors comprised lymphomas (two cases), meningioma (two), and meningeal sarcoma (one); inflammatory lesions comprised pyogenic abscesses (15 cases), granulomas (two), fungal infection (one), parasitic infection (one), and multiple sclerosis (two); included in infarcts was one case of radiation necrosis.

TABLE 2: Ring Visualization on Noncontrast CT Scans

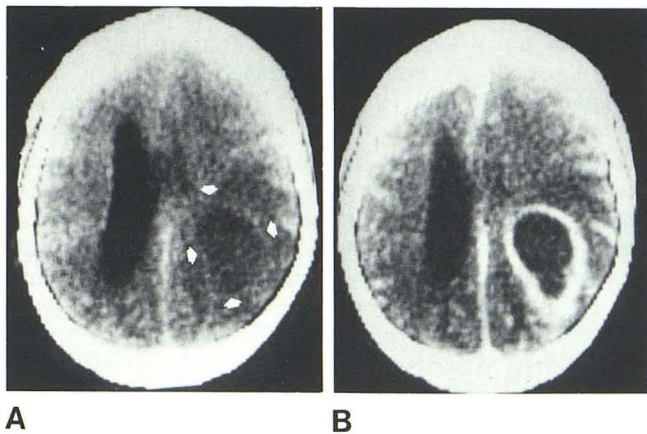| Degree of Ring Visualization	No. Cases (% of total)					
	Neoplasm	Inflammation	Infarct	Hematoma	Totals	
Complete	37 (57)	4 (19)	0	0	41	(35)
Incomplete or subtle	11 (17)	6 (29)	5 (28)	2 (22)	24	(21)
Absent	17 (26)	11 (52)	13 (72)	9 (82)	50	(44)
Totals	65 (56)	21 (18)	18 (16)	11 (10)	115	(100)

A   **B**

Fig. 3.—Abscess, complete ring on noncontrast scan. **A**, Unenhanced scan. Subtle, thin-walled ring (*arrows*) is less distinct than typically seen in neoplasms because of thin wall and paucity of surrounding edema. **B**, After contrast infusion. Smooth-walled, well defined ring is thicker than ring in **A** due to enhancement of abscess capsule plus compressed and ischemic brain surrounding abscess, a combination of pathoanatomic (abscess capsule) and pathophysiologic changes (breakdown of blood-brain barrier and neovascularity).
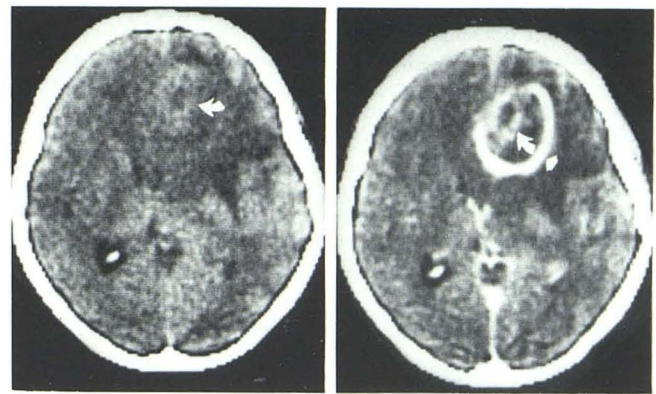

Fig. 5.—Glioma, incomplete ring. **A**, Unenhanced scan. Thick-walled irregular ring (*arrow*) surrounded by large area of edema. **B**, After contrast infusion. Ringlike density enhances (*curved arrow*), but is seen as part of larger, more well defined multilocular ring lesion (*straight arrow*). Thus, visualization of complete ring on unenhanced scan is misleading in this case, since ring visualized in **A** is not the complete lesion.
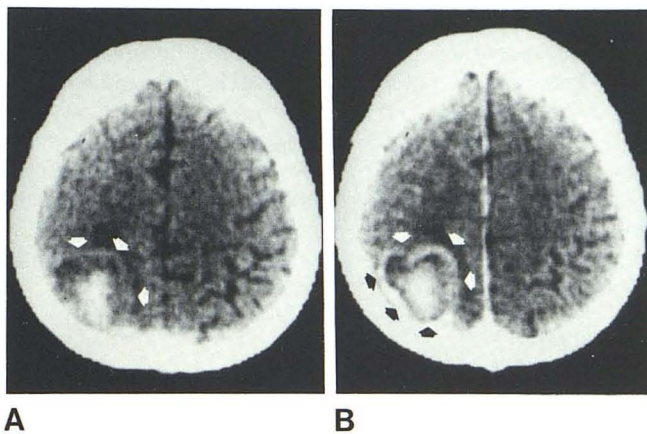

A   **B**

Fig. 4.—Aging hematoma, incomplete ring. **A**, Unenhanced scan. Hyperdense parietooccipital hematoma. Anterior and medial to hematoma and separated from it by thin halo of lucency, a thin well defined partial ring is identified (*arrows*) that does not extend around posterior medial and lateral aspects of hematoma as it approaches the cortex. Hyperdensity at this site is secondary to residual cortex and scan artifact. **B**, After contrast infusion. Well defined complete ring. Enhancement not only of previously identified anterior and medial parts of ring (*white arrows*) but also of posterior and lateral parts of ring (*black arrows*).
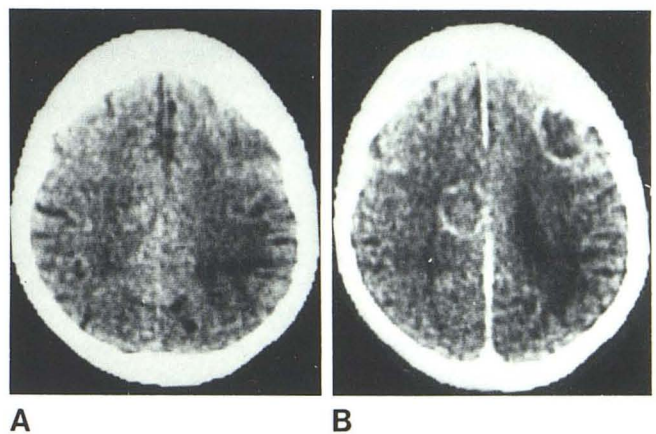

A   **B**

Fig. 6.—Multiple infarcts, no ring on noncontrast CT. **A**, Unenhanced scans. No ring densities. **B**, After contrast infusion. Two well defined rings in right para sagittal and left frontal convexity regions. Lesions are infarcts secondary to diffuse cerebral vasculopathy. They resolved on subsequent examination.

seen after contrast infusion permit some diagnostic differentiation.

Lesions that produce a ring density on noncontrast scans as well as after contrast cause a structural, pathoanatomic alteration in brain parenchyma. They are non–self-limiting or progressive lesions that, by their nature, require therapeutic intervention, usually surgical (i.e., neoplasms and abscesses).

Production of a complete ring easily seen in its entirety in at least one slice on noncontrast scans was found in 37 of

65 neoplasms and in four of 21 inflammatory lesions, all pyogenic abscesses. No infarcts or hematomas showed this phenomenon. Thus, a complete ring on the unenhanced CT scans excludes self-limiting processes such as infarct or hematoma.

A ring image has also been observed in partially thrombosed giant aneurysms, but none occurred during the time of this retrospective study. Incomplete or subtle ring densities or absent ring densities on the unenhanced scans proved to be of no differential diagnostic value, since either finding was seen with both self-limiting and progressive diseases.

Considering neoplasms with complete ring visualization only, a complete ring on noncontrast scans was seen most

TABLE 3: **Complete Ring Visualization on Noncontrast CT Scans: Type of Neoplasm**

Neoplasm	Total No. Cases	No. Seen (%)	
Metastasis	30	21	(70)
Glioma	30	11	(36)
Meningioma	2	2	(100)
Sarcoma	3	3	(100)
Totals	65	37	(57)

often in metastatic disease (70%) (fig. 1). Total absence of ring density was uncommon in metastatic disease (five of 30 cases). It is presumed that metastatic lesions produce unenhanced ring density because, grossly, they are usually well defined, circumscribed, and spheroidal in shape with a surrounding zone of softening and white matter edema [20]. In addition, there may be central softening and lique-faction necrosis [20, 21]. These pathologic phenomena provide a lower attenuation "background" (i.e., edema) and a lower density centrum, thus creating a rim of relatively hyperdense tissue corresponding to the ring-shaped periph-ery of the lesion.

The lower incidence of ring density on noncontrast scans in glioma (36%) is a reflection of the infiltrative growth pattern of these tumors and their indistinct demarcation from surrounding brain. It is of interest that only grades III and IV gliomas demonstrated complete rings on noncontrast scans. Pathologically, the more anaplastic lesions more often have central necrosis and peripheral neovascularity [21]. These features are resonsible for the ring image on noncontrast scans.

A ring density on noncontrast scans in pyogenic ab-scesses is not unexpected (four of 15 cases). Indeed, this phenomenon has been reported by several authors [4, 22]. The contrast enhancement seen in abscesses may be re-lated both to a pathophysiologic alteration and to a structural change depending on the stage of the infectious process. Ring lesions on contrast-enhanced scans have been re-ported in the early cerebritis stage [23], in which there is no anatomic basis for ring production. Encapsulation of an abscess along with formation of surrounding edema and central necrosis should allow visualization of a ring density on noncontrast scans. Capsule formation, however, is quite variable in the natural history of abscess, and is dependent on several factors, which include duration of disease, or-ganism characteristics, host resistance, pathogenesis, and location [24]. These account for the variable appearances of abscesses on noncontrast scans.

Pathophysiologic alterations in the brain parenchyma ad-jacent to a lesion may result in ring enhancement. These changes include a breakdown of the blood-brain barrier [6, 25] and localized increase in vascularity [26, 27]. When no specific structural change develops within the brain, visu-alization of a complete ring on noncontrast scans does not occur. Thus, a complete ring did not occur in 18 infarcts. Similarly, entities such as noninfectious inflammatory dis-ease and aging hematoma have no structural basis for ring formation and, therefore, were not expected to have com-

plete rings on noncontrast scans. Indeed, ring lesions were absent in these lesions. These lesions are regarded as nonprogressive and self-limiting, generally requiring no in-terventional theerapy. However, serial scans to resolution are recommended.

In the course of this study, we have applied strict criteria in categorizing the appearance of lesions on unenhanced scans. To fit our criteria of complete ring visualization on noncontrast scans, a complete, clearly definable ring must be observed in its entirety. Since an incomplete or subtle ring on noncontrast scans is occasionally seen in aging hematomas or infarcts (after resolution of mass effect), care must be used in assessing the completeness of the ring. It should be stressed that both the noncontrast and contrast-enhanced scans should be examined simultaneously. A density seen solely on the noncontrast scan may be mis-construed as representing a complete ring when, in fact, after contrast infusion, ring enhancement is found in a different location (fig. 5). Comparison of the characteristics of the lesion seen on noncontrast and contrast-enhanced CT is crucial to judgments about ring characteristics.

With the advent of higher-resolution CT scanners, ring visualization on noncontrast scans should be observed in a greater number of cases because of improved spatial and contrast resolution. This should increase the specificity and diagnostic accuracy of CT by aiding in differentiation be-tween progressive, potentially surgical lesions and self-lim-iting disease processes.

To recapitulate, a complete ring on the unenhanced CT scan excludes self-limiting nonprogressive lesions such as infarct or hematoma, and is more often seen in metastases than in abscess or glioma. An incomplete, subtle, or absent ring density on the noncontrast scan is of no differential diagnostic value.

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