



# The “hemorrhage exclusion” sign

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## Introduction

Magnetic resonance (MR) imaging has become an important tool in the diagnosis of prostate cancer as well as taking on roles in targeted biopsy, risk stratification, and treatment selection. Post-biopsy hemorrhage represents a potential limitation for precise detection as it may demonstrate T2 hypointensity, restricted diffusion, and altered contrast enhancement, which can mimic or obscure a cancer, particularly in the peripheral zone. However, its presence may potentially be exploited in turn. As originally described anecdotally for T1-weighted imaging, a sufficiently large tumor can be seen as a relatively hypointense lesion outlined by hyperintense residual blood products, producing the “hemorrhage exclusion” sign (Fig. 1) [1]. A proposed biochemical mechanism for this appearance is that cancer has significantly lower levels of citrate compared to normal tissues, thereby intuitively expected to contain lesser

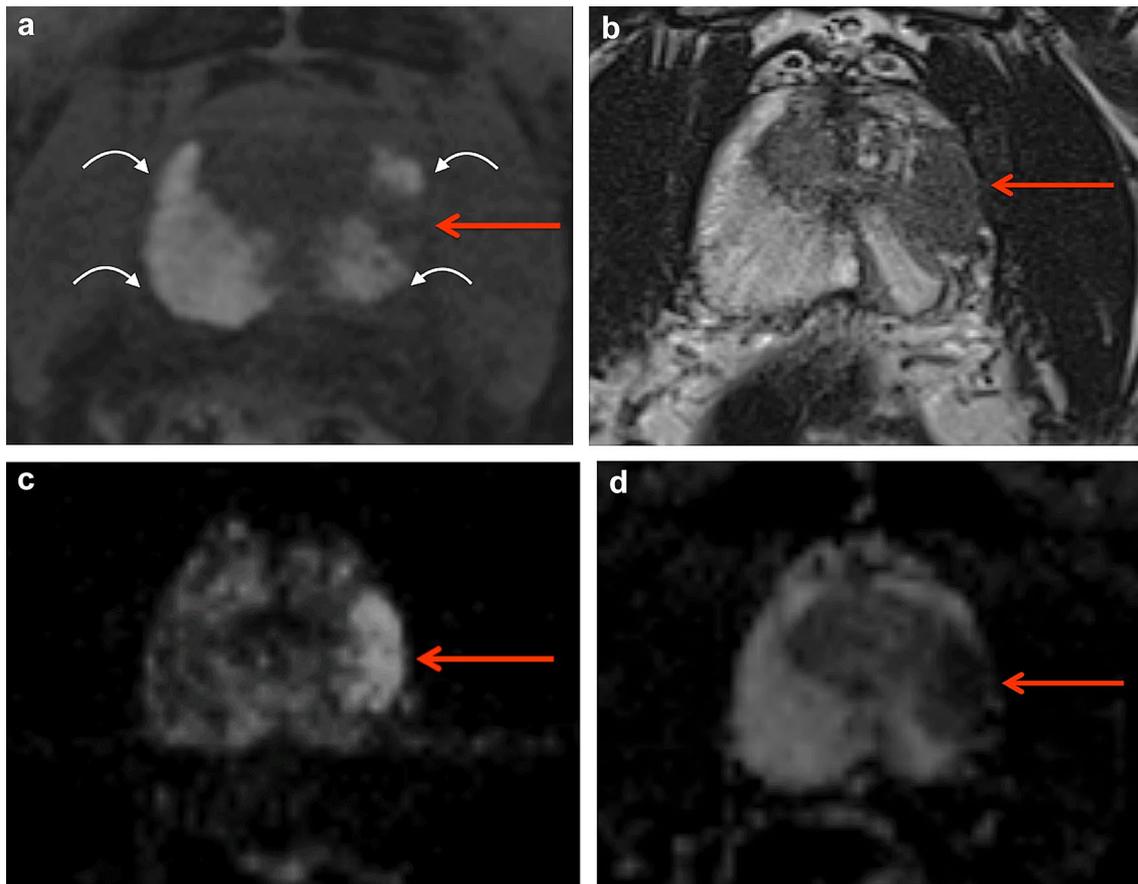
amounts of hemorrhage and have faster post-biopsy resorption than the surrounding normal peripheral zone. While the finding is of relatively low prevalence (~20%) and individually not a diagnostically powerful indicator (PPV = 50%), when applying the T1 hemorrhage exclusion in conjunction with T2-weighted images, the combined positive predictive value could approach 95% [2].

New and emerging techniques for T2- and diffusion-weighted imaging seek to mitigate the negative impacts of post-biopsy hemorrhage, and T1-weighted imaging is not a dominant parameter for current major standardized systems of MR interpretation (e.g. Prostate Imaging Reporting and Data System, PI-RADS) [3]. Nevertheless, when presented with a case where imaging has been performed in the post-biopsy setting, it is still important for the radiologist to recognize this sign to maximize the diagnostic yield of an MR study.

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**Fig. 1** Multiparametric MR prostate exam of a 59-year-old male with biopsy proven adenocarcinoma involving the left mid-gland peripheral zone, Gleason score of 4+3. Images were acquired only 10 days following biopsy. **a** Axial T1 fat-suppressed image shows hyperintense residual hemorrhage (curved white arrows) outlining a relative area of signal void (red straight arrow), illustrating the “hemorrhage

exclusion” sign. **b** Axial T2 image demonstrates a corresponding area of focal hypointensity (red arrow). **c** Diffusion-weighted image (high b-value of 1500 s/mm<sup>2</sup>) demonstrates marked hyperintensity in this region (red arrow) with associated ADC map showing marked hypointensity **d** consistent with restricted diffusion corresponding to the tumor (red arrow)

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

**Research involving human and animal rights** This article does not contain any studies with human participants or animals performed by any of the authors.

## References

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