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ORIGINAL ARTICLE

Magnetic resonance imaging as an adjunct diagnostic tool in computed tomography defined Bosniak IIF–III renal cysts: a multicenter study

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Abstract

Introduction CT imaging is the standard examination for renal cystic lesions and defines the Bosniak category, which dictates further management. Given that Bosniak II/IIF/III renal cystic lesions can potentially harbor renal cell carcinoma (RCC), additional diagnostic modalities may be required in management decision making.

Aim To determine the value of additional magnetic resonance imaging in CT-defined Bosniak IIF–III renal cystic lesions.

Materials and methods This a multicenter retrospective study of 46 consecutive patients, diagnosed with cystic renal lesions between 2009 and 2016. The inclusion criteria were: (1) cystic renal lesion classified as Bosniak IIF–III on CT, (2) a subsequent MRI examination, and (3) documented outcome via surgery for cystic renal mass or follow-up.

Results 46 patients (35 males, 11 females) were included. The mean size of the cystic lesion was 3.92 cm (0.7–10 cm). According to the CT findings, Bosniak IIF and III were found in 12 (26.1%) and 34 (73.9%) cases. Reclassification of Bosniak category was done after MRI examination in 31 cases (67.4%). An upgrade rate of 58.7% (27 cases) to a higher category was made, while the downgrade rate to a lower category was achieved in 4 cases (8.7%). As a result, significant therapeutic management change was made in 12/31 patients (38.7%), of whom 8 underwent subsequent surgery.

Conclusion MRI study may reduce the use of Bosniak IIF category (in comparison with CT), which has a direct impact on therapeutic management (surgery vs. surveillance) in a significant proportion of patients.

Keywords Renal cyst · Imaging · Kidney · Magnetic resonance · Cystic tumor

Introduction

Cystic renal lesions are found in approximately 50% of adults aged more than 50 years. While the majority of lesions are simple cysts and do not require any intervention

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or follow-up, a minority harbor malignant tumors [1, 2]. Computed tomography (CT) imaging is the standard imaging examination for characterization of renal cystic lesions. The Bosniak classification system is routinely used for classifying renal cystic masses on CT, which would dictate further management [3–5]. Importantly, this classification can also be used in MRI examinations [6].

An accurate diagnosis of Bosniak IIF and III in cystic renal masses is crucial, given that Bosniak IIF lesions are usually managed conservatively, while Bosniak III lesions are treated surgically. In this study, we evaluated the value of MRI in CT-defined Bosniak IIF/III renal cysts. Our aim was to establish whether MRI performed after CT examination yields additional information that can assist in guiding clinical management.

Materials and methods

Study design

This is a multicenter retrospective study from three European Urological Centers including Charles University, Medical Faculty and Charles University Hospital Plzen, Czech Republic, Medical University of Vienna, Austria, and Jagiellonian University Medical College, Kraków, Poland. We screened 213 consecutive patients who presented with Bosniak I–IV cystic renal lesions between January 2009 and December 2016 and were subsequently evaluated by CT imaging. All available clinical data were reviewed and re-evaluated. Inclusion criteria were: (1) cystic lesion of kidney classified originally as Bosniak IIF–III on CT, and 2) both CT and MRI examinations were performed. Of 213 patients, 46 met the inclusion criteria and enrolled in the study. All resected lesions were examined histologically and classified according to the 2016 WHO Classification of Tumours of the Urinary System and Male Genital Organs [7]. Further, the images from CT and MRI of 29 patients from Charles University, Medical Faculty and Charles University Hospital Plzen, Czech Republic, were reviewed by two radiologists, blinded to each other interpretations. The final description was used from the more senior and experienced radiologist.

Statistical analysis

The values of continuous parameters were calculated as mean ± standard deviation (SD). Pearson's χ^2 test was used for categorical variables. The performance of CT and MRI was assessed based on histopathological diagnosis or clinical follow-up, which served as the disease end point and gold standard. Sensitivity, specificity, predictive values, and percent agreements were calculated using the conventional contingency tables, and 95% confidence intervals (95% CI) computed using exact binomial methods. McNemar's χ^2 test was used to test the differences between sensitivities and specificities, as they were calculated using the same set of samples. Receiver operating characteristic (ROC) analyses were performed for CT and MRI examinations in detecting malignant lesions. Further, the area under the curve was calculated for each test as an alternative single indicator of test performance. An interrater reliability analysis using the *Kappa* statistic was also performed to determine consistency among the radiologists interpreting a subset of CT and MRI images. All tests were two-tailed, and $P < 0.05$ was considered statistically significant. All descriptive and inferential statistical analyses were carried out using the Statistical Package for the Social Sciences (SPSS), version 19.0 (Chicago, IL, USA).

Results

Of 46 patients, 35 were male (76.1%) and 11 were female (23.9%). Patient's age ranged from 29.5 to 84 years (median 60.25 years, mean 60.15 years). The size of the cystic lesions ranged from 0.7 to 10 cm (mean 3.92 cm, median 3.25 cm). The right kidney was affected in 21 cases (45.7%) and the left kidney in 25 cases (54.3%) (Supplementary Material Table 2).

According to the CT imaging, Bosniak IIF was present in 12 cases (26.1%) and Bosniak III in 34 cases (73.9%). In subsequent MRI examination, Bosniak category I was present in 3 cases (6.5%), Bosniak II in 1 case (2.2%), Bosniak IIF in 1 case (2.2%), Bosniak III in 16 cases (34.8%), and Bosniak IV in 15 cases (32.6%). In 10 cases (21.7%), papillary renal cell carcinoma (PRCC) was suspected on MRI imaging (Supplementary Material Table 2). The original CT-defined Bosniak category was changed as the result of MRI findings in 31 cases (67.4%). The upgrade rate to a higher category was made in 27 cases (58.7%) while downgrade was seen in 4 cases (8.7%). Both upgrade and downgrade rates led to change in therapeutic management in 12 cases (8/12 patients underwent surgery and 4/12 patients remained under periodic clinical follow-up) (Supplementary Material Table 3). Subsequently, 41 of the 46 cystic renal lesions were removed surgically. Seven patients underwent nephrectomy (17%), and 34 lesions (83%) were removed by nephron sparing surgery. It should be noted that 10 cases which were initially classified on CT as Bosniak categories IIF/III were subsequently reclassified as suspicious for PRCC based on MRI findings.

All resected lesions were examined histologically. The spectrum of histological findings in appropriate Bosniak category (according to MRI) is summarized in Table 1. Overall, benign cysts were found in one Bosniak I and one in Bosniak IIF. Category Bosniak III included a wider spectrum

Table 1 The spectrum of histological findings according to Bosniak categories (MRI)

Bosniak category	Histological findings		Note	
Bosniak I	Benign cyst	1/3 case	2/3 cases are without any treatment	
Bosniak IIF	Benign cyst	1/1 case (100%)		
Bosniak III	CCRCC	4/16 cases (25%)		
	MCRNLMP	7/16 cases (43.75%)		
	MEST	2/16 cases (12.5%)		
	MA	1/16 case (6.25%)		
	Simple renal cyst	2/16 cases (12.5%)		
Bosniak IV	PRCC type 1	6/15 cases (40%)	2/15 cases active surveillance	
	CCRCC	4/15 cases (26.7%)		
	PRCC type 2	1/15 case (6.7%)		
	CCPRCC	1/15 case (6.7%)		
	MCRNLMP	1/15 case (6.7%)		
PRCC	PRCC	10/10 cases (100%)	PRCC type 1	6/10 cases (60%)
			PRCC type 2	1/10 cases (10%)
			PRCC NOS	3/10 cases (30%)

of histological findings including simple renal cyst (2/16 cases in this category, 12.5%), multicystic renal neoplasia of low malignant potential (MCRNLMP) (in previous WHO classification 2004 recognized as multilocular cystic renal cell carcinoma [8]) in 7/16 cases (43.8%), clear cell renal cell carcinoma (CCRCC) in 4/16 cases (25%), mixed epithelial and stromal tumor (MEST) in 2/16 cases (12.5%) and metanephric adenoma (MA) in 1/16 cases (6.3%). Histological findings in Bosniak IV category included PRCC type 1 (6/15 cases in this category, 40%), CCRCC in 4/15 cases (26.7%), PRCC type 2 in 1/15 cases (6.7%), MCRNLMP in 1/15 cases (6.7%), and clear cell papillary renal cell carcinoma (CCPRCC) in 1/15 case (6.7%). In 10 cases, PRCC was suspected on MRI imaging, and histologic examination further confirmed the diagnosis of PRCC in all cases.

The sensitivity of MRI for the detection of malignant renal cystic lesions was 100%, compared with 82.4% for CT. When the CT data were adjusted based on subsequent MRI examinations (cases which were initially defined by CT as cystic and subsequently reclassified as solid by MRI), the CT sensitivity was reduced to 77.2%. In terms of specificity, both CT and MRI showed equal figures. No statistical significant differences were found between sensitivities/specificities of CT vs. MRI in detecting malignant renal cystic lesions. The ROC curve for CT compared with MRI in detecting malignant cystic lesions is shown in Fig. 1. In this analysis, the areas under the curve for CT (0.551) and MRI (0.639) were found to be similar ($P > 0.05$). The ROC analyses showed similar findings between MRI and CT with and without adjusted data (Fig. 1).

The results of the interrater analysis between the two radiologists (Supplementary Material Table 4) interpreting a subset of 29 CT images showed a *Kappa* statistics of 0.269 ($P = 0.011$). The corresponding *Kappa* statistics for MRI images interpretation between the two radiologists was 0.581 ($P < 0.0001$).

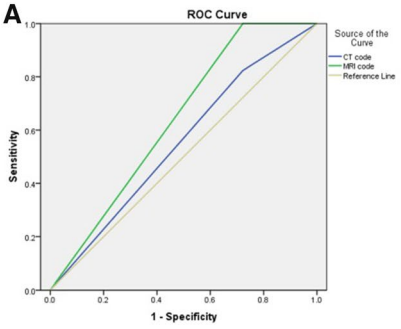
Discussion

Renal cysts are common incidental findings during CT evaluation. Nonetheless, there is only a relatively small proportion of renal tumors which may present as cystic neoplasm (8–10% of renal tumors) [2, 9].

Traditionally, the classification of renal cystic lesions is based on radiological imaging (i.e., CT) and the Bosniak classification system [3, 4, 10, 11]. The radiologic diagnostic criteria for Bosniak classification were first published in 1986, with four Bosniak categories [10]. However, currently five Bosniak categories are recognized. The added fifth category (Bosniak IIF) is used for cystic lesions, which are not complex enough to be classified as Bosniak III, yet these lesions are more complex than what is seen as Bosniak II category [11–13]. Individually Bosniak categories are associated with different risk of malignancy and therapeutic management.

The risk of malignancy in renal cystic lesions during CT evaluation is assessed based on morphologic and structural features and contrast enhancement of different cyst components (i.e., content, septa, calcifications, solid component) [3, 11, 14]. There are a number of studies in the literature which assessed malignity rate in each Bosniak category [15–17]. At one end of the spectrum, Bosniak II category lesions seem to behave in a benign fashion and with low risk of malignant behavior, which do not require further treatment or follow-up [3, 13]. At the other end of the spectrum,

A



Area Under the Curve

Test Result Variable(s)	Area	Std. Error[a]	Asymptotic Sig.[b]	Asymptotic 95% Confidence Interval	
				Lower Bound	Upper Bound
CT code	.551	.098	.609	.358	.743
MRI code	.639	.095	.161	.454	.824

The test result variable(s): CT code, MRI code has at least one tie between the positive actual state group and the negative actual state group. Statistics may be biased.
a. Under the nonparametric assumption
b. Null hypothesis: true area = 0.5

B

	CT (unadjusted)*	CT (adjusted)**	MRI	CT (unadjusted) vs MRI	CT (adjusted) vs MRI
Sensitivity	82.4%	77.8%	100.0%	> 0.05	> 0.05
Specificity	27.8%	27.8%	27.8%	> 0.05	> 0.05
False Positive rate	72.2%	72.2%	72.2%		
False Negative rate	17.6%	22.2%	0.0		
Positive Predictive Value	51.9%	61.8%	56.7%		
Negative Predictive Value	62.5%	45.5%	100.0%		
Percent agreement	54.3%	57.8%	62.9%		

Fig. 1 Statistical analysis. **a** ROC curve for MRI compared with CT in detecting malignant renal cystic lesions. **b** Comparison of CT and MRI examinations in detecting malignant renal cystic lesions. *Based on original CT findings, the data in this category were not adjusted according to the subsequent MRI examination. **The data in this category were adjusted according to the subsequent MRI examination

Bosniak IV category lesions are typically associated with higher risk of malignancy, requiring surgical treatment [6, 10, 13, 18].

Bosniak categories IIF and III are challenging entities, both diagnostically and therapeutically. Bosniak III category presents with malignity rate of 50% (intermediate risk of malignancy) [15]—true malignant lesions as well as renal neoplasms with indolent behavior are also diagnosed in this category. Given these lesions cannot be distinguished by preoperative imaging [19], the treatment is inevitably surgical. Bosniak IIF lesions have malignity rate of approximately 25% [15]. This category includes a broad range of lesions such as malignant tumors, lesions with indolent behavior as well as benign lesions. Therapeutic management of these lesions still remains controversial and that there is no consensus protocol (despite various proposed recommendations in the literature) as how best to manage such lesions. Bosniak et al. proposed a follow-up CT imaging 6 months after initial examination. If there is no progression, the patient can be placed on surveillance on annual basis [12]. Weibl et al. suggested CT follow-up on Bosniak IIF lesions every 6 months during the first 2 years and then continued annually. In addition, the authors suggested at least an MRI examination during follow-up, especially in the early phase at ≤ 4 years [16, 20].

Bosniak classification system is also used in MRI imaging. In fact, MRI can better detect internal architectures of renal cystic lesions due to its higher contrast resolution than CT. However, MRI findings should be used with caution because of risk of overestimation of Bosniak categories [6].

In our study, there were two cases (4.3%) classified as Bosniak III category on MRI, which were histologically described as a simple renal cyst. In these two cases, MRI led to overtreatment of the patients. In 10 cases of Bosniak III category, lesions with benign or indolent behavior (MESTK, MCRNLMP, MA) were also found. All these tumors were treated surgically, which can be perceived as overtreatment, given that clinical follow-up should have been sufficient in these patients. It is worth noting that even histologic diagnoses may not always be easy and straightforward. For instance, MESTK can be misdiagnosed as other tubulocystic tumors, such as tubulocystic RCC or even fumarate hydratase-deficient RCC. The diagnosis of MCRNLMP can be established after careful consideration of grade and exclusion of any expansive nodules. MA can be very similar to Wilms tumor or less usual variants of PRCC.

Recent studies have shown that MRI may be more favorable and accurate than CT in evaluating renal cystic lesions. MRI has high contrast resolution, multiplanar capabilities, lack of ionizing radiation, depiction of additional septa and thickening of the wall and/or septa (Fig. 2), better characterization of enhancement (facilitated by subtraction imaging) [21–24]. MRI is also not associated with phenomenon of pseudoenhancement, which has been noted to occur more commonly with CT technology [25]. In this study, we demonstrated that MRI examination performed after initial CT imaging led to change in Bosniak classification in 31 cases (67.4%), with an upgrade rate of 58.7% (27 cases) and downgrade rate of 8.7% (4 cases). Ultimately, these reclassifications led to change in therapeutic management in 12/31 patients, including 8 patients who underwent surgery.

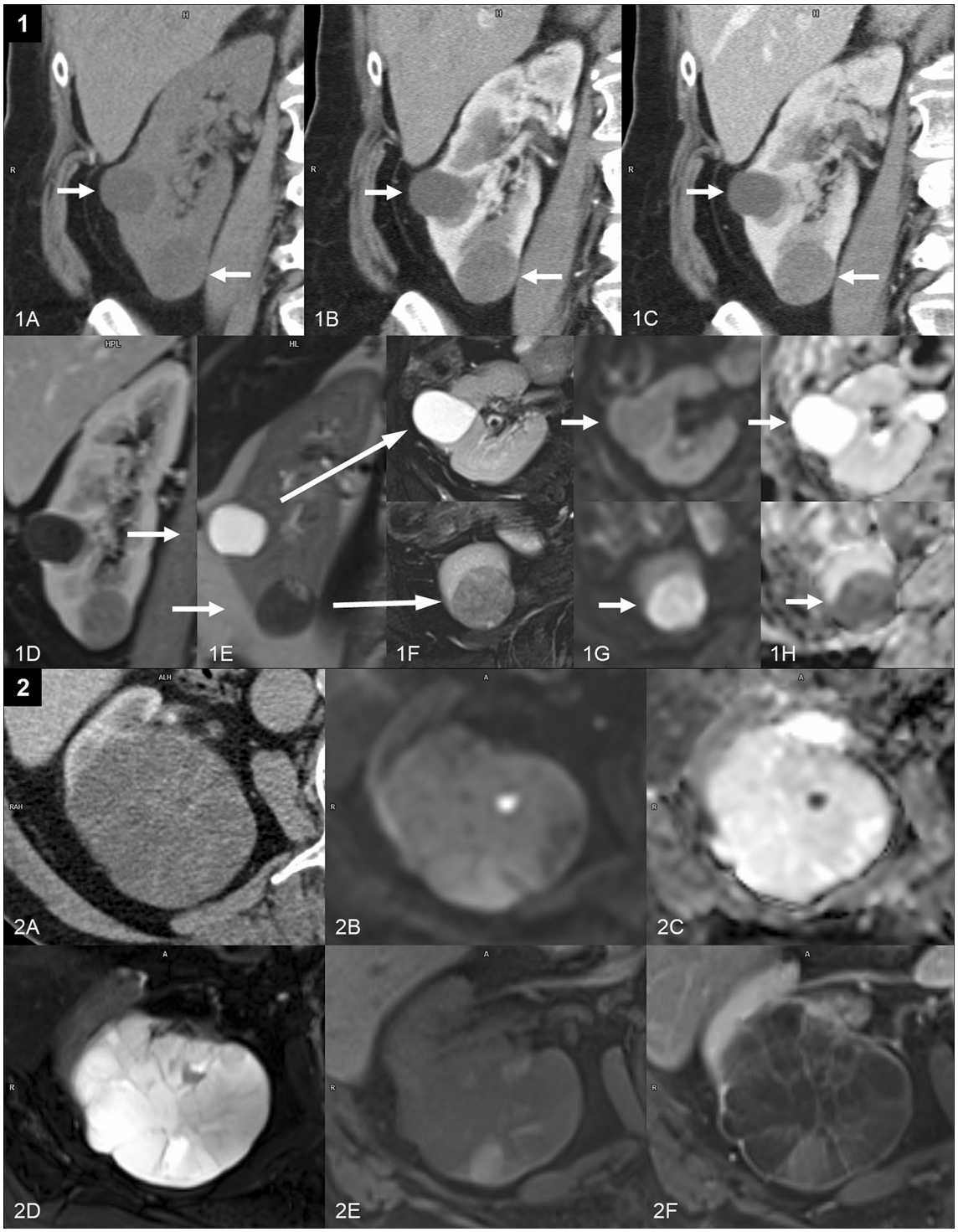


Fig. 2 **1** The picture shows two cystic lesions in the same kidney—the upper arrow line shows renal cyst classified according to CT as Bosniak I (homogenous signal of water with free diffusion), the lower arrow shows the lesion originally described as cyst Bosniak IIF based on CT, after MRI examination Bosniak IIF lesion was reclassified as PRCC (different signal characteristics, non-homogenous structure, restricted diffusion). Noncontrast CT (**1A**), CT after iv. contrast administration in arterial (**1B**) and venous phase (**1C**). MR imaging in contrast-enhanced T1 fat suppressed (**1D**), T2 (**1E**), T2 fat suppressed (**1F**), DWI *b* factor = 800 s/mm^2 (1G), ADC (**1H**). **2** Complicated renal cyst: MRI better showed marked heterogeneity of the inner structure of the lesion that was suspected from tumor origin (histology confirmed multilocular cystic renal neoplasm of low malignant potential). Contrast-enhanced CT (**2A**) and MRI: DWI *b* factor = 800 s/mm^2 (**2B**), ADC (**2C**), T2 fat suppressed (**2D**), T1 fat suppressed imaging before (**2E**) and after intravenous contrast agent administration (**2F**)

Ferreira et al. reported similar findings in their cohort of 37 patients with change in Bosniak categories based on MRI results. The authors showed that therapeutic management changed in 7/15 of their patients with upgraded categories [17].

We believe that MRI can be helpful in diagnostically challenging cases of Bosniak IIF category. In our study, only one case was diagnosed as Bosniak IIF on MRI (compared with originally 12 Bosniak IIF cases on CT). This suggests that MRI examination may allow the radiologist classifying cystic lesions as Bosniak II or III rather than Bosniak IIF, which will directly impact clinical management. This may be owing to more accurate imaging of septa, better detection of contrast enhancement and more precise imaging of inner structure and content of the lesions. Further, we demonstrated a perfect agreement (100%) between all 10/10 cases which were classified as suspicious for PRCC on MRI and final histopathologic diagnosis of PRCC. Thus, this may suggest MRI as a good diagnostic modality in PRCC differential diagnosis.

Although an accurate radiologic assessment on preoperative imaging is demanded, it is well recognized that the utility of both CT and MRI highly depends on radiologists' experience which is associated with a wide interobserver variability [26]. In this study, an interrater reliability analysis was performed to determine consistency among radiologists interpreting a subset of 29 patients with CT and MRI images. The measure of agreement for the CT group was "fair" (*Kappa* = 0.269). On the other hand, the *Kappa* agreement value for the MRI group between the two radiologists was considered "moderate" (0.581). Overall, a preferred *Kappa* value (to be at least 0.6) was not achieved to claim a good level of agreement. This may further support the fact that CT imaging may be more limited in its subjective assessment of renal cystic lesions compared with MRI.

Conclusion

MRI seems to be a better imaging method for evaluation of complex renal cystic lesions. Our findings showed a superior sensitivity of MRI in detecting malignant lesions. MRI can potentially reduce the use of Bosniak IIF category, which has a direct impact on therapeutic management. We suggest MRI to be considered as the next step in diagnostic algorithm in cystic lesions classified as Bosniak IIF–III on CT. Despite clear advantages of MRI, the results have to be evaluated with caution with regard to the possibility of Bosniak category overestimation, which can eventually lead to overtreatment of the patient.

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Authors' contribution TP, project development, Manuscript writing, Data collection or management, Data analysis; KP, Manuscript writing/editing; RT and RA, Data analysis, Manuscript editing; TB, Data analysis; IT, KP and PC, Data collection or management; TK, Data collection or management, Manuscript editing; OH and MH, Manuscript editing.

Compliance with ethical standards

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

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Retrospective study For this type of study formal consent is not required.

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