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INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE

Efficacy and safety of percutaneous thermal ablation in Bosniak III and IV cystic renal masses: a systematic review and meta-analysis

Hans-Jonas Meyer[1]
Timo Christian Meine[2]
Manuel Florian Struck[3]
Silke Zimmermann[4]

[1]University of Leipzig, Department of Diagnostic and Interventional Radiology, Leipzig, Germany

[2]Hannover Medical School, Department of Diagnostic and Interventional Radiology, Hannover, Germany

[3]University Hospital Leipzig, Department of Anesthesiology and Intensive Care Medicine, Leipzig, Germany

[4]University Hospital Leipzig, Institute of Laboratory Medicine, Clinical Chemistry and Molecular Diagnostics, Leipzig, Germany.

PURPOSE
Local thermal ablation is considered a standard treatment for small kidney masses. However, few studies have investigated the efficacy and safety of thermal ablation for cystic kidney masses.

METHODS
The MEDLINE library, Cochrane, and SCOPUS databases were screened for studies investigating the efficacy of thermal ablation for cystic renal masses, comprising studies between 1995 and February 2024. In total, seven studies were deemed suitable and included in the present analysis.

RESULTS
The studies included a total of 113 participants with 134 cystic renal masses. The sample sizes ranged from 5 to 38 participants. There were 76 men (67.2%) and 37 women (32.8%), with a mean age of 64.7 years (range: 50 to 75.4 years). Overall, 55 cystic masses were classified as Bosniak III (41%) and 79 as Bosniak IV (59%). Technical success of local thermal ablation was reported in 133 cystic masses (99.2%). The pooled meta-analytic technical success rate was 100% [95% confidence interval (CI): 96%–100%, $I^2 = 0.0\%$]. Complications were reported in 9 cases (6.7%). According to the Society of Interventional Radiology classification system, there were 3 major complications (2.6%) and 6 minor complications (5.3%). The pooled meta-analytic complication rate was 10% (95% CI: 5%–20%, $I^2 = 40\%$). No tumor recurrence was reported during follow-up.

CONCLUSION
Local thermal ablation can be considered a highly effective and safe procedure for cystic kidney masses. Most studies were performed using radiofrequency ablation, underscoring the need for further studies on alternative ablation techniques such as microwave ablation and cryoablation.

CLINICAL SIGNIFICANCE
Local thermal ablation is an effective and safe procedure for treating cystic kidney masses.

KEYWORDS
Meta-analysis, systematic review, percutaneous thermal ablation, renal cell carcinoma

Renal cell carcinoma (RCC) is the most common malignant renal tumor, representing over 30,000 cases every year in the United States of America (USA).[1] Besides surgical resection, a promising treatment option for small RCCs (stage 1) is percutaneous thermal ablation, most commonly performed with radiofrequency ablation (RFA) and microwave ablation (MWA).[2-6]

Percutaneous thermal ablation is a widely accepted minimally invasive treatment for surgically unresectable RCC, with good published results in small solid renal tumors and a high reported efficacy, with complete ablation rates ranging from 90% to 100%.[4,7] However, not all malignant renal tumors are solid masses, as cystic renal masses can also harbor malignancy.[8,9]

Corresponding author: Hans-Jonas Meyer

E-mail: hans-jonas.meyer@medizin.uni-leipzig.de

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According to the renal cyst classification, Bosniak III or IV cystic lesions may carry a particular risk for malignancy, even if some of these lesions (particularly Bosniak III) are proven to be benign after biopsy or surgery.[8-10] Based on the Bosniak category, the risks of malignancy for Bosniak III and IV lesions were 16%–100% and 90%–100%, respectively.[8,11]

Due to the high risk of malignant transformation in Bosniak III and IV cysts, thermal ablation has been utilized as a possible treatment option instead of surgery.[12] Partial nephrectomy remains the most commonly used treatment for Bosniak III and IV cysts. In some cases with high perioperative morbidity, active imaging-based surveillance can be justified.

Yet, the cyst composition, particularly the presence of a solid tumor component, could influence the outcome of thermal ablation.[13] One can assume that the differing tissue composition of cystic renal masses induces variable heating effects during local thermal ablation and may also impact the outcome of this treatment modality. However, reliable systematic data comparing these aspects between cystic and solid renal masses have not yet been published. Moreover, although thermal ablation is included in guidelines for the treatment of solid renal masses, these recommendations cannot yet be translated to cystic renal masses.[3]

It is noteworthy that only a few retrospective studies have investigated the efficacy and safety of thermal ablation in cystic renal masses, and a recent overview of the published literature is needed. Notably, no previous systematic review and meta-analysis have been conducted to investigate the outcomes of thermal ablation in cystic renal masses. Therefore, the purpose of the present systematic review and meta-analysis was to elucidate the efficacy and safety of local thermal ablation in participants with cystic kidney masses.

Main points

- Local thermal ablation of cystic renal masses is an effective and safe procedure.
- The data is mainly comprised for radiofrequency ablation and few microwave ablation ablations, whereas there is no data for cryoablation.
- Prospective evaluations are needed.

Methods

The institutional review board approved the meta-analysis.

The present analysis is an analysis of published results for which no ethics approval and informed consent is required

Data acquisition

The MEDLINE library, Cochrane, and SCOPUS databases were screened for studies investigating local thermal ablation of cystic renal masses. No other sources were used for data acquisition. The timeframe of the study search included studies between 1995 and February 2024. The paper acquisition process is summarized in Figure 1.

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement (2020) was used for the analysis.[14] The following search words were used: "radiofrequency ablation" OR "microwave ablation" OR "local thermal ablation" AND "renal mass" OR "cystic renal mass" OR "renal cyst."

The primary endpoints of the systematic review were the technical success rate of thermal ablation and the complication rate. Studies (or subsets of studies) were included if they satisfied the following criteria: (1) cystic renal mass, (2) treatment by local thermal ablation with RFA or MWA, and (3) reported technical success rate defined by complete coverage of the ablation zone of the cystic renal mass. The exclusion criteria were as follows: (1) systematic reviews, (2) case reports, (3) non-English language, and (4) solid renal mass. In total, seven studies were included in this analysis.[12,15-20]

Data extraction

Data extraction was performed by two authors (HJM and SZ), followed by an independent evaluation of the extracted data for correctness (MFS). For each study, details regarding study design, year of publication, country of origin, participant number, participant characteristics (age and sex), histopathological diagnosis, ablation type, ablation time, and Bosniak category[8] were extracted.

Quality assessment

The quality of the included studies was assessed using the Newcastle–Ottawa Scale (NOS).[21] Study quality assessment was conducted by two authors (SZ and HJM). In cases

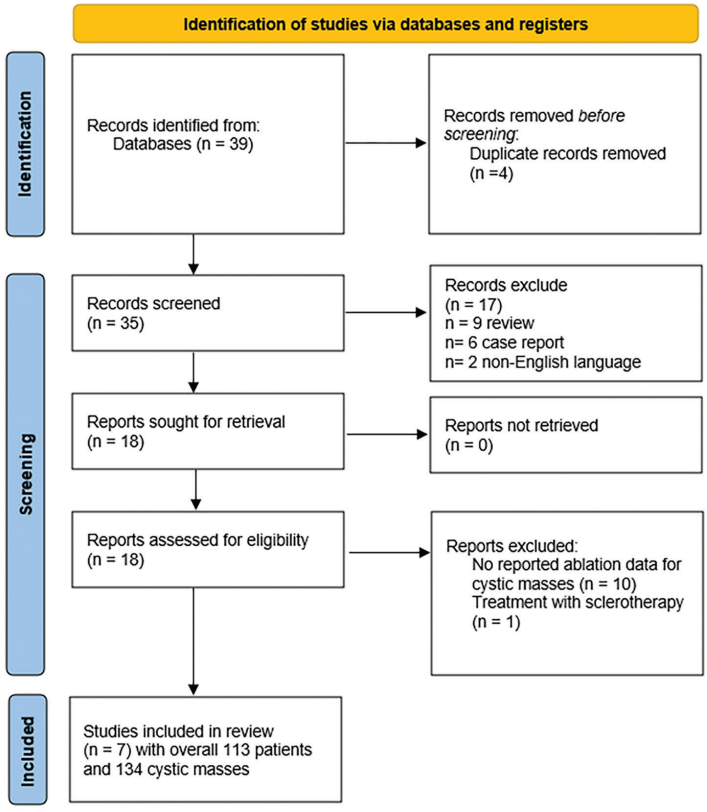

Figure 1. PRISMA flow chart (2020) providing an overview of the paper acquisition process. Overall, seven studies with 113 participants and 134 treated cystic masses were included in the analysis. PRISMA, The Preferred Reporting Items for Systematic Reviews and Meta-Analyses.

of disagreement, consensus was reached by a third author. The NOS assesses the quality of studies based on the selection of cases, comparability of the cohort, and outcome assessment of exposure to risks. A score of 0–9 was assigned to each study, and a score ≥6 was considered indicative of high quality.

Statistical analysis

The meta-analysis was performed using RevMan 5.3 (2014; Cochrane Collaboration, Copenhagen, Denmark). Heterogeneity was assessed using the inconsistency index I^2.[22,23] The proposed thresholds for I2 according to the Cochrane Handbook are as follows: 0% to 40%: might not be important; 30% to 60%: may represent moderate heterogeneity; 50% to 90%: may represent substantial heterogeneity; 75% to 100%: considerable heterogeneity.[24] DerSimonian and Laird[25] random-effects models with inverse variance weights were applied without further correction.

Results

Quality of the included studies

All included studies had a retrospective design. Table 1 provides an overview of the included studies. The overall risk of bias for the current research question can be considered low, indicated by high NOS values among the studies, with scores of 8 points (Table 2). However, there is a lack of information regarding long-term oncological outcomes in the included studies.

Participants

The included studies comprised a total of 113 participants with 134 cystic masses. The sample sizes ranged from 5 to 38 participants. There were 76 men (67.2%) and 37 women (32.8%), with a mean age of 64.7 years (range: 50 to 75.4 years). Three studies (42.7%) were conducted in North America (USA), two studies (28.5%) in Asia (South Korea), one study (14.4%) in South America (Brazil), and one study (14.4%) in Europe (Italy).

In total, 55 cystic masses (41.0%) were classified as Bosniak III and 79 cystic masses (59.0%) as Bosniak IV. The mean lesion size was 2.5 cm, ranging from 1.1 to 10.1 cm. In five studies (71.4%), RFA was used to treat 122 cystic masses (91.0%), whereas in two studies (28.6%), MWA was used to treat 12 cystic masses (9.0%).

Only one study,[20] involving 5 cystic masses, employed an aspiration technique prior to ablation; all other studies inserted the needle directly into the cystic mass. Three studies did not perform a pre-ablation biopsy.[15,18,19] Regarding histopathological confirmation, 60 of the 134 masses (44.4%) had a definitive diagnosis. Clear-cell carcinoma was diagnosed in 44 cystic masses, papillary carcinoma in 6 masses, and 10 lesions were diagnosed as undifferentiated carcinoma. The remaining 75 cystic masses (55.6%) had no definitive tumor diagnosis.

Technical success

Technical success of local thermal ablation was reported in 133 of 134 cystic masses (99.2%). The pooled meta-analytic technical success rate was 100% [95% confidence interval (CI): 96%–100%, I^2 = 0%; Figure 2]. No tumor recurrence was reported after ablation in the included studies. A potential selection bias should be acknowledged when interpreting the technical success rate.

Complication rate

Complications were reported in 9 cases (6.7% of ablations). The pooled meta-analytic complication rate was 10% (95% CI: 0.05%–20%, I^2 = 40%; Figure 3). Park et al.[19] reported two iatrogenic pneumothoraces requiring chest tube placement. In a previous study by Park et al.[18], four complications were reported: one arteriovenous fistula, one case of inguinal paresthesia, and two pneumothoraces. Allen et al.[12] reported three complications: one major case of flash pulmonary edema requiring emergency department transfer, and two minor complications–dysuria and mild hydronephrosis due to a blood clot in the ureter, both managed conservatively.

Using the classification system of the Society of Interventional Radiology,[26] there were 3 major complications (2.6% of all cases) and 6 minor complications (5.3% of all cases).

Discussion

This study is the first systematic review and meta-analysis on the success and complication rates of treating cystic renal masses with thermal ablation techniques. As shown, the technical success rate can be considered very high, with a reported rate of 100%. Moreover, the procedure can be considered safe, with a complication rate of 10% and no major events. In two cases, iatrogenic chest tube placement was needed due to pneumothoraces. No major bleeding events or cyst ruptures were reported in the included studies. The present results are therefore well comparable to published results in solid renal masses.[4,6]

However, a possible selection bias should be acknowledged for the very high success rate, as potential negative cases may not have been published in the literature. There will be cases in clinical routine with cystic components that are too large, and without full ablation coverage of the lesion. This should be kept in mind when interpreting the present results.

Notably, the studies included in this analysis did not report the size limits for which local ablation can still be considered treatable, raising further concerns about selection bias.

In a large recent meta-analysis, outcomes of RFA and MWA were reported for 2,258 ablations.[27] As in the present analysis, all studies were retrospective in nature. The primary technical efficacy rate of MWA was comparable to RFA, with a reported odds ratio = 0.89 (95% CI: 0.52%–1.51; I^2 = 0%).[26] The complication rate was also not substantially different between the two methods.

In a meta-analysis by Choi et al.[7], the efficacy and safety of MWA for malignant renal tumors were analyzed. Overall, 13 articles with 616 renal masses were included. A very high efficacy rate of 97.3% (95% CI: 94.3%–99.4%; I^2 = 0%) was reported, in line with our present results. The reported major complication rate was lower, at 1.8% (95% CI: 0.6%–3.3%; I^2 = 0%).[7] Notably, the differences in complication rates should be discussed, as the reported complications of bleeding, hematoma, and pseudoaneurysm in the analysis by Choi et al.[7] were of a more severe quality compared with those reported in the present analysis. This likely explains the differences. Similar safety and efficacy results were reported in RFA analyses,[28] supporting the conclusion that both ablation methods can be considered equally effective and safe.

One important aspect of the current meta-analysis is that there were not enough cases to compare the treatment outcomes between RFA and MWA specifically for cystic renal masses, as only a few cases were treated with MWA. There is a definite need to further investigate the differences between the methods in cystic renal masses.

Another important technique for local thermal ablation is cryoablation, which has shown promising results for small renal masses.[29] However, no studies to date have reported on its use for cystic renal masses, which needs to be investigated in the future.

Notably, there are also no reports regarding long-term oncological outcomes for local thermal ablation.[30] Moreover, the cooling dynamics of cystic areas in the kidney may differ substantially from the heating mechanisms of RFA and MWA.

Table 1. Demographics and ablation characteristics of the included studies

Authors	Country	Study design	Included patients (n)	Cystic masses (n)	Mean age (years)	Technical success, n (%)	Gender female, n (%)	Performed biopsy	Bosniak III (n)	Bosniak IV (n)	Ablation technique	Complication, n (%)	Mean lesion diameter (cm) ± SD	Ablation time (min)	Localization	Follow-up
Allen et al.[12]	USA	Retrospective	38	40	71	40 (100)	19 (47.5)	During the ablation	25	15	RFA	3 (7.5)	2.3 (1.0–4.2)	n.a.	n.a.	33.8 months (range 12–78)
Carrafiello et al.[15]	Italy	Retrospective	6	7	74	7 (100)	1 (16.7)	No biopsy	1	6	MWA	0	1.7 (1.4–2.7)	10	7 exophytic	24 months
Menezes et al.[16]	Brasil	Retrospective	9	10	63.5	10 (100)	4 (44.4)	4 during ablation; 5 without biopsy	0	10	RFA	0	2.5 (1.5–4.1)	12	8 exophytic, 2 central	27 months (interquartile range, 23–38)
Felker et al.[17]	USA	Retrospective	16	23	62	21 (91.3)	5 (31.3)	During the ablation	7	16	RFA	0	3.1 (1.1–10.1)	n.a.	16 exophytic, 7 central	24 months (range 2–110)
Park et al.[18]	South Korea	Retrospective	9	14	50	15 (100)	1 (11.1)	No biopsy	5	9	RFA	4 (26.7)	2.5 (1.6–3.9)	6	10 exophytic, 5 central	8 months (range 1–19)
Park et al.[19]	South Korea	Retrospective	30	35	57	35 (100)	5 (16.7)	No biopsy	15	20	RFA	2 (5.7)	2 (1.1–4.3)	18	n.a.	24 months (range 6–70)
Zhou et al.[20]	USA	Retrospective	5	5	75.4	5 (100)	2 (40)	During the ablation	2	3	MWA	0	3.3 (2.3–5.2)	8.6	3 exophytic, 2 central	18 months (range, 6–36)

SD, standard deviation.

Table 2. Quality of the included studies based on the Newcastle-Ottawa Scale

Study	Case definition adequate	Representativeness of cases	Selection of controls	Definition of controls	Comparability of cases and controls	Ascertainment of exposure	Same method of ascertainment	Non-response rate	Quality score
Allen et al.[12]	*	*	*	*	*	*	*	*	8
Carrafiello et al.[15]	*	*	*	*	*	*	*	*	8
Menezes et al.[16]	*	*	*	*	*	*	*	*	8
Felker et al.[17]	*	*	*	*	*	*	*	*	8
Park et al.[18]	*	*	*	*	*	*	*	*	8
Park et al.[19]	*	*	*	*	*	*	*	*	8
Zhou et al.[20]	*	*	*	*	*	*	*	*	8

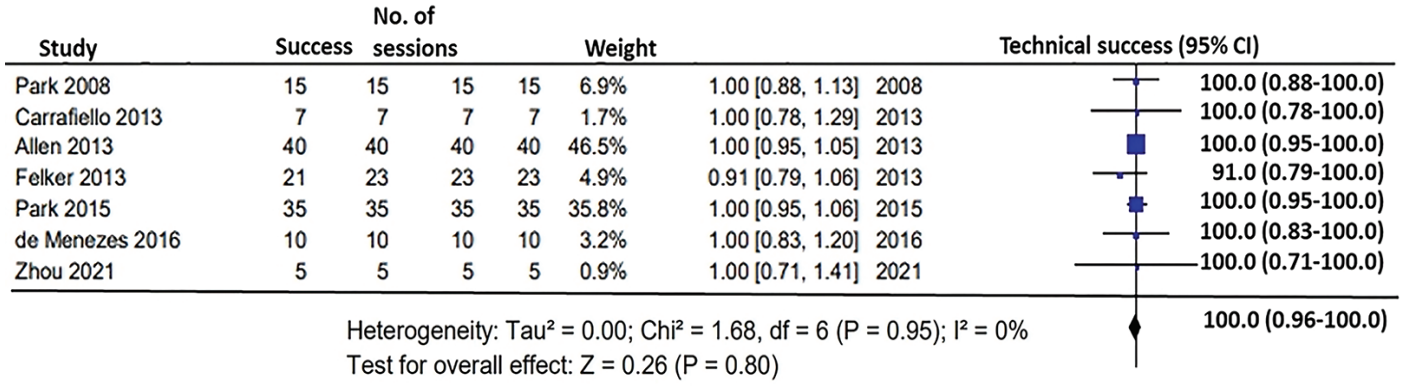

Figure 2. Forest plot of the technical success rate of thermal ablation. The pooled technical success rate was 100% (95% CI: 96%–100%, I^2 = 0%). CI, confidence interval.

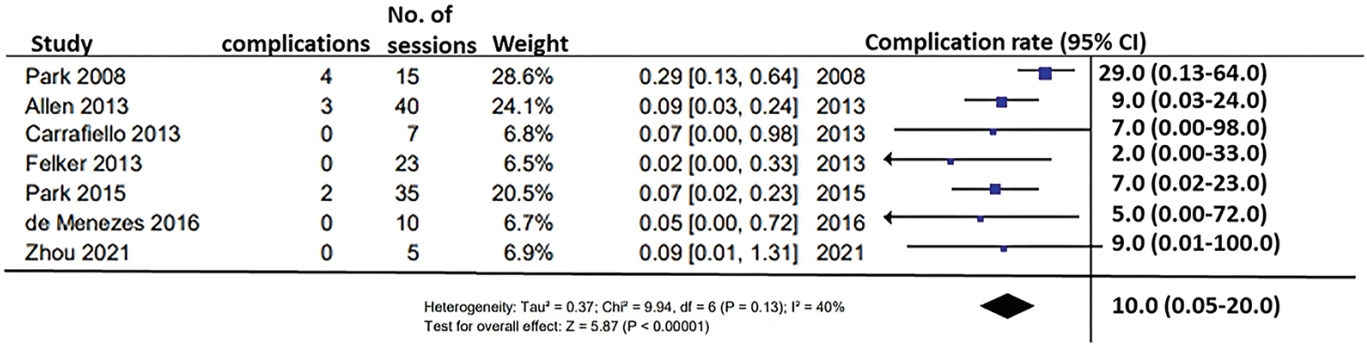

Figure 3. Forest plot of the complication rate of thermal ablation. The pooled complication rate was 10% (95% CI: 0.05%–20%, I^2 = 40%). CI, confidence interval.

Not every included study performed a biopsy prior to ablation. It therefore remains unclear whether every Bosniak III cyst treated was indeed a malignant mass. In a large meta-analysis, the malignancy rate of Bosniak III cysts was 55.1% (95% CI: 45.7%–64.5%), and for Bosniak IV cysts, 91% (95% CI: 87.7%–94.2%).[8] This raises the question of whether some Bosniak III cysts might be better suited for imaging surveillance rather than immediate definitive treatment with surgery or ablation.[31] However, treatment for both Bosniak III and IV cysts is currently recommended in the guidelines.[3]

The outcome of local thermal ablation is affected by factors such as lesion location, lesion size, ablation time, tissue impedance, and electrode surface area.[17,31] There may also be differences between MWA and RFA, especially regarding the heat sink effect, to which RFA is more susceptible.[5,6] Hypothetically, this is particularly relevant in cystic masses, as their fluid content may lead to a substantial heat sink effect. This could favor MWA in achieving full ablation of the mass. However, no direct comparison between RFA and MWA has been published to date, and such a comparison was not possible in the current meta-analysis.

One important aspect is also that the lesion composition and complexity–due to multilobulations and septae–could have an important impact on the treatment result. However, there is no reliable information in the included studies regarding the complexity of the cystic masses, and it remains unclear

which imaging features of cystic renal masses have a clinically relevant impact on the outcome of ablation.

There is no systematic data or guideline on how to follow up with patients after local ablation treatment for cystic renal masses. One can only assume that follow-up for patients with cystic renal masses should be similar to that for solid renal masses. According to this, follow-up is recommended during the first year at 1, 3, 6, and 12 months, and thereafter every 12 months with contrast-enhanced cross-sectional imaging.[32,33] Presumably, regrowth of the cystic component alone should be considered tumor recurrence. However, as mentioned above, there is no data or published experience regarding tumor recurrence after ablation for cystic renal masses.

Notably, there are also no reports regarding long-term oncological outcomes after local ablation of cystic renal masses. One can only assume that outcomes should not differ from those of solid renal masses, provided full ablation of the lesion is achieved.

The present meta-analysis has several limitations to address. First, it is based on small published participant cohorts. Moreover, the included studies were retrospective case series without control groups, resulting in a low level of evidence. In addition, there was no direct comparison with surgical procedures in a randomized controlled trial. The overall level of evidence for these studies is considered level 5. Second, the analysis was restricted to English-language publications. Third, no long-term oncological outcomes were reported in the included studies. However, it seems plausible that no substantial recurrence occurred when the ablation zone covered the entire cystic mass with a safety margin. Fourth, comparisons between RFA and MWA were not possible, as only two studies investigated MWA. Fifth, the included studies used the older version of the Bosniak cyst classification, which was updated in 2019 to include more sophisticated assessments of septa and solid components.[10] However, there may be no substantial changes to the classification of Bosniak III and IV cysts.[32] Sixth, only one study reported aspiration of the cyst content prior to ablation. It remains unclear whether aspiration was performed in the other studies but not reported, or whether it was not performed at all. This should be addressed in future research. Seventh, there may be a publication bias in the analysis; however, we could not assess this, as tests for publication bias are recommended only when more than 10 studies are included.[24]

In conclusion, local thermal ablation can be considered a highly effective and safe procedure for cystic kidney masses. Most studies were performed using RFA, highlighting the need for new studies investigating MWA and cryoablation.

Footnotes

Conflict of interest disclosure

The authors declared no conflicts of interest.

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