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Transarterial embolization (TAE) as add-on to percutaneous radiofrequency ablation (RFA) for the treatment of renal tumors: Review of the literature, overview of state-of-the-art embolization materials and further perspective of advanced image-guided tumor ablation

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ABSTRACT

Percutaneous radiofrequency ablation (RFA) for the treatment of stage I renal cell carcinoma has recently gained significant attention as the now available long-term and controlled data demonstrate that RFA can result in disease-free and cancer-specific survival comparable with partial and/or radical nephrectomy. In the non-controlled single center trials, however, the rates of treatment failure vary. Operator experience and ablation technique may explain some of the different outcomes. In the controlled trials, a major limitation is the lack of adequate randomization. In case reports, original series and overview articles, transarterial embolization (TAE) before percutaneous RFA was promising to increase tumor control and to reduce complications. The purpose of this study was to systematically review the literature on TAE as add-on to percutaneous RFA for renal tumors. Specific data regarding technique, tumor and patient characteristics as well as technical, clinical and oncologic outcomes have been analyzed. Additionally, an overview of state-of-the-art embolization materials and the radiological perspective of advanced image-guided tumor ablation (TA) will be discussed. In conclusion, TAE as add-on to percutaneous RFA is feasible and very effective and safe for the treatment of T1a tumors in difficult locations and T1b tumors. Advanced radiological techniques and technologies such as microwave ablation, innovative embolization materials and software-based solutions are now available, or will be available in the near future, to reduce the limitations of bland RFA. Clinical implementation is extremely important for performing image-guided TA as a highly standardized effective procedure even in the most challenging cases of localized renal tumors.

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1. Introduction

Percutaneous radiofrequency ablation (RFA) is established for the treatment of localized renal tumors [1–3]. Attempts have been made to describe the role of tumor ablation (TA), surgery, and surveillance in the interdisciplinary management of clinical stage I renal cell carcinoma (RCC) by considering so-called quality indicators [4,5]. Now, long-term data are available and the considerable increase of use and acceptance of image-guided RFA is not only justified by the convincing oncologic outcomes, but also by demography and the zeitgeist: older patients having comorbidity and metachronous renal tumors, strong evidence and growing awareness of renal insufficiency, diabetes mellitus and hypertension as major predictors for cardiovascular morbidity and mortality, interdisciplinary tumor boards, cost-effectiveness, informed consent and patient laws [1–3,6–9].

In adequately selected patients, percutaneous RFA can be carried out with a very low complication rate, preservation of the renal function and high oncologic success [10]. According to a meta-analysis, the major and overall complication rates after RFA of small renal tumors are 4–6% and 8–13%, respectively [11].

For a controlled trial with T1a renal tumors, Takaki et al. published comparable 5-year disease-free and cancer-specific survival rates between RFA, partial nephrectomy and radical nephrectomy (98.0% vs. not available [n.a.] vs. 94.2% [not significant (n.s.)] and 100% vs. 100% vs. 100% [n.s.], respectively) [12]. In a controlled trial with T1b renal tumors, 5- and 10-year disease-free as well as cancer-specific survival rates were also comparable between RFA and radical nephrectomy (88% vs. 84.0% [n.s.] and 88.0% vs. 84.0% [n.s.] as well as 94% vs. 100.0% [n.a.] and 94.0% vs. 100.0% [n.a.], respectively) [13]. In the same study, however, the 5- and 10-year overall survival rates were superior in favor of radical nephrectomy (63.0% vs. 97.0% and 48.0% vs. 97.0% [$p < 0.0009$, respectively]).

According to a recently performed systematic meta-analysis on treatment failure after percutaneous RFA of renal tumors, relative frequencies for residual non-ablated tumor, local tumor progression, recurrence within a kidney outside of the ablation zone and extra-renal metastasis were 5.9%, 4.7%, 1.3% and 2.0%, respectively [14]. The review demonstrates that local control of the primary renal tumor is of particular clinical relevance, and further strategies are justified to avoid local treatment failure. In this context, tumor size (>3.0 cm) and location (central) must be regarded as the most relevant predictors of treatment failure. To better control high-risk tumors, RFA has been used in combination with transarterial embolization (TAE). In the first instance, the combined approach seems to be effective for the control of larger T1 tumors and the reduction of ablation-associated complications [2,15,16]. Since publications include case reports, original series and overview articles with inconsistent reporting, we performed a systematic review and analysis of the literature. Additionally, an overview of state-of-the-art embolization materials was given and the further perspective of advanced image-guided TA outlined.

2. Materials and methods

2.1. Systematic review and analysis of the literature – RFA in combination with TAE

Original studies on image-guided percutaneous RFA in combination with TAE for renal tumors were eligible for inclusion. A systematic literature search was carried out. The search algorithm in MEDLINE (PubMed) consisted of specific text words: “radiofrequency ablation”, “RF ablation”, “RFA”, “kidney tumor”, “renal cancer”, “renal tumor”, “renal cell carcinoma”, “RCC”, “embolization”, “transarterial embolization”, “image-guided” and “percutaneous”. After this first selection, titles and abstracts of the retrieved articles were screened and potentially appropriate articles defined (second selection). Third selection included a detailed evaluation of the main bodies and reference lists of the retrieved articles. Finally, only original studies giving specific data for technique of RFA and TAE, tumor and patient characteristics as well as technical, clinical and oncologic outcomes were included (fourth selection). Filtration and analysis of articles were conducted in accordance with the PRISMA statement, whereby the four consecutive steps of selection corresponded to the flow of information through the different steps of a systematic review (identification, screening, eligibility and inclusion) (Fig. 1) [17]. The methodological quality of the studies that are potentially appropriate for inclusion was checked by using the Downs and Black checklist for systematic reviews of non-randomized studies [18]. Systematic review and analysis were performed by CMS, DV and LPW, and completed in December 2015.

2.2. Overview of state-of-the-art embolization materials

The established embolization materials were analyzed. Rationale as well as clinical and/or experimental data for the kidney were given.

2.3. Further perspective of advanced image-guided TA

Emerging technologies for image-guided TA were described. Those included (I) percutaneous TA systems beyond RFA, (II) innovative embolization materials and (III) advanced techniques for treatment planning, guidance and control.

2.4. Clinical index scenarios

Index scenarios were defined to specify high-risk settings for clinical TA in the kidney. To illustrate the value of specific techniques and technologies, different cases were illustrated.

3. Results

3.1. Systematic review and analysis of the literature – RFA in combination with TAE

Seven original studies report specifically on percutaneous RFA in combination with TAE including a total of 67 renal tumors in 59 patients [15,16,19–23]. None of these studies is a randomized controlled trial. Patient, tumor and treatment characteristics are listed in Table 1. In the vast majority of cases, RFA in combination with TAE was performed in patients with significant comorbidity (e.g. reduced renal function) and high-risk for ablation-associated hemorrhage (e.g. need for multiple applicator passes). In all cases, TAE was performed before RFA, whereby the time interval ranged between several hours and one week. The tumor size ranged between 3.5 cm and 9.0 cm. Tumor configuration included exophytic, endophytic, central or mixed locations as well as presence or absence of tumor hypervascularity on pre-interventional CT and/or MRI. Different embolization materials such as ethanol, iodized oil, resorbable gelatin sponge and polyvinyl alcohol (PVA) particles with sizes between 150 and 250 μm and 500–700 μm, or a combination, were used for selective or superselective embolization. All RFA procedures were performed under CT-guidance, however different RFA devices were used. Protocols included an ablation time between 3 min and 17 min, a power between 50 W and 200 W and a target tissue temperature between 65 °C and 105 °C. In the entire collective, two abscesses and three hematomas were described as major complications [19,23]. In the study with the longest follow-up (47.0 ± 3.8 months), the local tumor control rate, metastasis-free