Systematic Review and Meta-Analysis

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The primary treatment of prostate cancer with high-intensity focused ultrasound

A systematic review and meta-analysis

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Abstract

Background: We systematically evaluated the evidences on oncological and functional outcomes of high-intensity focused ultrasound (HIFU) as the primary treatment for localized prostate cancer (PCa).

Methods: A systematic review was used Medline, Embase, and the Cochrane Library from the inception of each database. The review analyzed the oncological and functional outcomes of HIFU in the treatment of PCa. The RevMan 5.3 software was used for quantity analysis incidence of complications.

Results: Twenty-seven articles were included for analysis with a total of 7393 patients. Eighteen studies investigated the whole-gland HIFU, and the duration of follow-up ranged from 2 to 168 months. After whole-gland HIFU, the mean prostate-specific antigen (PSA) nadir was found to be 0.4 to 1.95 ng/mL and the mean time to PSA nadir was 2.4 to 5.4 months. The rate of positive biopsy after HIFU was 4.5% to 91.1%. Meta-analysis revealed the incidences of urinary incontinence, impotence, urinary obstruction, retention, and infection was 10%, 44%, 15%, 11%, 7%, respectively. Nine studies investigated partial-gland HIFU, and the duration of follow-up was 1 to 131 months. After partial-gland HIFU, the mean PSA nadir was 1.9 to 2.7 ng/mL and the mean time to PSA nadir 5.7 to 7.3 months. The rate of positive biopsy after HIFU in the treatment area was 14% to 37.5%. Meta-analysis revealed the incidences of urinary incontinence, impotence, urinary obstruction, retention, and infection was 2%, 21%, 2%, 9%, 11%, respectively.

Conclusions: Early evidence suggested the partial-gland HIFU was safer than whole-gland HIFU, and they had similar oncological outcomes. More prospective randomized controlled trials of whole-gland and partial-gland HIFU for PCa was needed.

Abbreviations: ADT = androgen-deprivation therapy, AUR = acute urinary retention, BCR = biochemical recurrence, BDFS = biochemical disease-free survival, BOO = bladder outlet obstruction, DFS = disease-free survival, HIFU = high-intensity focused ultrasound, mpMRI = multiparametric magnetic resonance imaging, OS = overall survival, PCa = prostate cancer, PSA = prostate-specific antigen, RALP = robot-assisted laparoscopic prostatectomy, RCT = randomized controlled trial, TURP = transurethral resection of prostate.

Keywords: high-intensity focused ultrasound, high-intensity focused, prostate cancer, systematic review, treatment

1. Introduction

The incidence of prostate cancer (PCa) is currently the second highest of all male malignant tumors.[1] At the present, standard treatments for PCa include radical prostatectomy and radiotherapy, but there are some limitations, such as the possibility of intraoperative bleeding, or intraoperative/radiation injury to surrounding tissues, and poor repeatability of results. Therefore, novel methods for the treatment of PCa have been developed. High-intensity focused ultrasound (HIFU) is considered to be promising, due to:

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YH and PT contributed equally to this work.

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(1) it can be monitored in real time during surgery by ultrasound;
(2) it can be used to evaluate the border of necrosis immediately postoperatively through contrast-enhanced ultrasound;
(3) it can be performed repeatedly if necessary;
(4) It is almost noninvasive.[2]

The goal of HIFU is to heat malignant tissues above 65°C, resulting in the destruction of these tissues through coagulative necrosis. The HIFU has been used for PCa treatment in many centers around the world for more than 20 years. However, the current guidelines do not regard HIFU as the first-line treatment for PCa, and the benefits of whole- versus partial-gland ablation, transurethral resection of prostate (TURP), and androgen-deprivation therapy (ADT) before HIFU remain unclear. Therefore, this study performed a systematic review to evaluate the oncologic and functional outcomes of whole-gland or partial-gland HIFU ablation for the primary treatment of PCa.

2. Methods

2.1. Scoping

Ethical approval and informed consent were not necessary because of the nature of the design of this study. The research question was formulated as follows: "what are the efficacy and side effects of HIFU in the primary treatment of localized PCa?" Table 1 illustrates the PICOS (population, intervention, comparison, outcomes, study design) format.

2.2. Search strategy

We performed a systematic review in accordance with PRISMA guidelines. Terms including "Prostate Cancer," "High-Intensity Focused Ultrasound," "Prostate Neoplasms," "Prostatic Cancer," and "Prostatic Neoplasms" were used to systematic search PubMed, Embase, and the Cochrane Library date to December 20, 2019.

Table 1

PICOS (population, intervention, comparison, outcomes, study design) format.

Research question	Description
Population	Included: men with PCa Excluded: men with recurrent PCa
Intervention	Included: HIFU in primary therapy Excluded: HIFU in salvage therapy
Comparison	Included: whole-gland/partial-gland HIFU Excluded: other treatment options
Outcomes	Included: oncological and functional outcomes Excluded: Imaging results
Study design	Included: randomized controlled trial (RCT), case series, prospective studies, retrospective series Excluded: reviews, conference or poster presentation, editorial commentaries

2.3. Study selection

Results were limited to studies published in English. After search were carried out, 2 researchers (YH and MJH) screened the titles and abstracts independently to identify potentially relevant articles. In the case of a disagreement, a third senior researcher (PT) arbitrated. During quality review, studies were excluded if they included overlapping patient cohorts, or included <50 participants (Fig. 1).

2.4. Data analysis

For baseline demographics, the denominator was the total number of patients who received HIFU therapy. When reporting positive biopsies following treatment, the denominator was the number of men who underwent biopsy. With regards to the rates of impotency and incontinence after HIFU, the denominator was

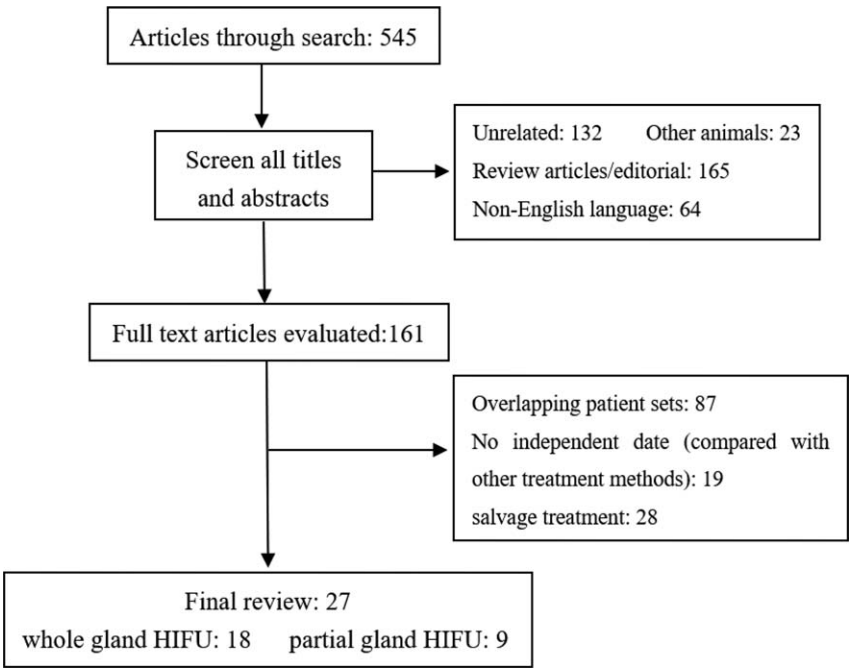

Figure 1. PRISMA flowchart of study selection with excluding reasons.

the number of men with normal baseline function before prostate ablation. Studies were not included if the data was 0 in the meta-analysis with noncomparative binary data.

Incidence of complications after HIFU was analyzed with χ^2 tests. P-value $< .05$ was accepted as statistically significant.

Urinary obstruction included bladder outlet obstruction (BOO) and urethral strictures. Biochemical recurrence (BCR) was defined according to the Stuttgart definition (a rise of $\geqslant$1.2 ng/mL above the nadir prostate-specific antigen [PSA]), Phoenix definition (a rise $\geqslant$2 ng/mL above the nadir PSA), or the Horwitz definition (2 consecutive increases of at least 0.5 ng/mL, backdated). Treatment failure was defined as BCR, positive biopsy post-ablation, or requirement for salvage treatment.

3. Results

3.1. Whole-gland HIFU

Eighteen studies were identified and a total of 5695 patients treated from 43.6 to 88 years old were reported (Table 2).[3–20] The majority of patients had stage T1-T3 disease; 10 studies included cases with T3. The mean or median pre-HIFU PSA was 5 to 10 ng/mL. More than 70% of the patients were diagnosed with low- or intermediate- risk disease. The duration of follow-up was 2 to 168 months. In most studies, repeat biopsy was performed at 3 to 6 months after HIFU treatment or due to PSA elevation.[3,5,7,8,10–14,16,17,19] One study performed biopsies at 6 to 12 months after treatment,[4] and another study did biopsy at 6 weeks after treatment.[19]

3.1.1. Oncological outcomes. After HIFU treatment, the nadir PSA and the time to PSA nadir were shown in Table 3. The 5-year overall survival (OS) rate had been reported to be 100%[11] and 90%[4] by 2 studies, and the 8-year OS rate was reportedly 83% from 1 study,[4] 2 studies reported that the 10-year OS rate was 80%[7] and 88.6%,[20] respectively. The PCa-specific 5-year and 8-year survival rates have been reported to be 100% from 2 case series[4,11] and 98%.[4] The metastasis-free survival rate was found to be 98.4% at 5 years in 1 study,[11] and ranged from 78.1% to 96% for >5 years from 3 case series.[7,8,13]

According to Phoenix definition the biochemical disease-free survival (BDFS) rate ranged from 77% to 88% at 5 years from 4 series,[4,6,8,16] while 4 other case series report this rate to be 48.1% to 75% for >5 years.[4,7,8,13] When stratified by risk category in 9 reports, lower the BDFS was found to be associated with higher risk.[4,8,9,11–14,17,18] However, Blana et al[4] reported that the 5- and 7-year BDFS rates were 77% and 69% with no statistical difference between low- and intermediate-risk patients. The 7- and 10-year disease-free survival (DFS) rates have been reported to be 59%,[4] and 48.8%,[20] respectively. The DFS rate was found to be significantly different between low- and intermediate-risk patients.[4] The rate of positive biopsy after HIFU treatment ranged from 4.5% to 91.1%.[3–5,7,8,10–14,16–20]

3.1.2. Functional outcomes and complications. At 3 months after HIFU, the prevalence of Grade I, II, and III urinary incontinence was 0.7% to 18.7%, 0.7% to 40.5%, and 0% to 1.2%, respectively. The incidence of impotence was 30.7% to 65.6%.[4,6,9,13,17,18,20] The rates of urinary incontinence and impotency were found to be 10% (95% confidence interval [CI] 0.06–0.14, $P < .00001$) and 44% (95% CI 0.35–0.52, $P < .00001$) in the meta-analysis (Table 3 and Fig. 2).

The incidences of BOO and urethral strictures have been reported to be 0.8% to 35.1%[7–9,12,20] and 3.6% to 19.7%,[4–7,10,13,19,20] respectively; the incidence of urinary obstruction has been reported as 13.6%,[4] 14.5%,[17] 15.9%[18] from 3 different studies. The rates of urinary retention and infection were 7.6% to 25%[5,7,18,19] and 3.9% to 13.8%,[4,7,10,19] respectively. The rectourethral fistula rate ranged from 0% to 1.2% in the included studies.[5,7,8,10,13,19,20] Ganzer et al[8] reported that all cases with rectourethral fistula were underwent repeated HIFU. Meta-analysis revealed that the incidence of urinary obstruction, retention, and infection were 15% (95% CI 0.10–0.20, $P < .00001$), 11% (95% CI 0.07–0.16, $P < .00001$), and 7% (95% CI 0.03–0.12, $P < .00001$), respectively (Table 3 and Fig. 2).

3.2. Partial-gland HIFU

Nine case series reporting on a total of 1698 patients from 45 to 81 years old were identified (Table 4).[21–29] Most patients were stage T1 or T2 PCa, only 2 studies included patients with stage T3 PCa.[25,28] All of the pre-HIFU mean/median PSA levels were $\leqslant$8 ng/mL. Only 1 study included high-risk patients (representing 22% of the study population).[25] TURP was only performed in patients at risk of urinary retention or to prevent early acute urinary retention (AUR).[21,29] The duration of follow-up ranging from 1 to 131 months. Among the studies, systematic biopsy plus targeted biopsy with fusion magnetic resonance imaging (MRI) are reported.[21,22,24,27] There was only 1 study in which patients underwent a single ultrasound-guided puncture, with range number of cores being 20 to 69.[23] In most studies, patients underwent repeat biopsy 12 months after HIFU treatment or due to PSA elevation,[21,22–25,29] while another study performed biopsy at 6 months after treatment.[26]

3.2.1. Oncological outcomes. After HIFU treatment, the nadir PSA and the time to PSA nadir were shown in Table 3. The median time to PSA nadir was reportedly 3 months.[29] The maximum decrease in PSA from baseline at 6 months after treatment was 65.7% in the included studies.[26] The OS rate was reported in 3 studies: the 1-, 2-, 5-, and 8-year survival rates were 99%, 99%, 97%, and 97%,[28] respectively, while at follow-up was 96.3%,[25] at 5 years was 87%.[29] The PCa-specific survival rates were 100% at 5 years[29] and follow-up[25] in 2 case series. The metastasis-free survival rate was 93% at 5 years from 1 study.[29]

When defined according to the Phoenix definition, the BDFS was reported to be 90.3%,[23] 45% when defined according to the Stuttgart definition, and 58% according to the Phoenix definition.[29] The BDFS rate was reported to be significantly lower for patients categorized as intermediate-risk compared with low-risk.[29] After HIFU treatment, re-biopsies were carried out in the case of PSA rise or suspected lesions from MRI findings. The rate of positive re-biopsy was 19.6% to 70.1%,[22,23–27,29] and with the positive rate in the treatment area being 14% to 37.5%.[22,24,27,29]

3.2.2. Functional outcomes and complications. At 3 months after HIFU, the incidence of urinary incontinence was reported to be 0% to 6%,[22–27,29] and Mortezavi et al[26] and Feijoo et al[23] reported rates of 0%. The incidence of impotence was reportedly 14% to 47.6%.[23–25,27,29] Meta-analysis revealed the incidences of urinary incontinence and impotence were 2% (95% CI 0.01–0.03, $P = .004$) and 21% (95% CI 0.14–0.29, $P < .00001$) (shown in Table 3 and Fig. 3).

Table 2

Summary of studies of whole-gland high-intensity focused ultrasound.

Author	Country	Study design	Patients, no.	Age of patients	Risk classification	PSA (ng/mL)	TURP prior or combined with HIFU	ADT prior HIFU	Follow-up	More than 1 HIFU session
Berge et al[3] 2014 1 HIFU vs more than 1 HIFU	UK	Retrospective, 3 centers	229 vs 130	Mean(rage) 65.9 (46.7–87.4) vs 64.6 (43.6–80.5)	NR	Mean (SD) 7.9(6.4) vs 8.3(5.0)	NR	26.7%	median (range) 27 (3–81) mo	Redo HIFU: 36.2%, 2 redo sessions: 5.3%, 3 redo sessions: 0.3%.
Blana et al[4] 2008	Germany and France	Retrospective cohort study, 2 centers	140	Median (range) 70 (45–87)	Low and intermediate risk of AJCC: 51.4% and 48.6%	Mean (SD) 7.0 (3.5)	0	16.4%	Mean (SD, range) 6.4 (1.1, 5.0–8.8) yr	Mean (SD) 1.3 (0.49)
Bolton et al[5] 2015	Australia	Prospective, single center	103	Median (SD, rage) 69.5 (8.67, 48–87)	Low, intermediate, High risk of D' Amico: 47.2%, 38.9%, 13.9%.	PSA: 0–4.0 (12.9%), 4.1–10.0 (57.4%), 10.1–20.0 (27.8%), >20.0 (1.9%)	NR	25%	Mean >12 mo	Single
Chiang et al[6] 2016	Taiwan of China	Retrospective, single center	120	Mean (SD) 68.06 (1.91)	Low, intermediate, high risk of D' Amico: 12.5%, 39.2%, 48.3%	Mean (SD) 17.04 (21.88)	100%	NR	Mean (SD)32.68 (11.87) mo	NR
Crouzet et al[7] 2014	France	Prospective, single center	1002	Median (range) 71 (48–87)	Low, intermediate, high risk of D' Amico: 35.6%, 45.1%, 17.4%	Median (range) 7.7 (0.0–30.0)	93.7%	39.1%	median (range) 6.4 (0.2–13.9) yr	1 session: 60%, 2 sessions: 38%, 3 sessions: 2%
Ganzer et al[8] 2013	Germany	Retrospective, single center	538	Mean (rage) 67.7 (7)	Low, intermediate, high risk of D' Amico: 42.6%, 39.2%, 16.9%	Mean (SD) 11.2 (19.7)	77.3%	36.4%	Mean (SD; range) 8.1 (2.9, 2.1–14.0) yr	1 session: 78.6%, 2 sessions: 20.6%, 3 sessions:0.8%
Hatiboglu et al[9] 2017	Germany	Prospective, single center	131	Mean (SD) 72.8 (6.0)	Low, intermediate, high risk of D' Amico: 29.0%, 58.8%, 12.2%	Mean (SD) 9.6 (14.9)	83.2%	21.4%	Mean (SD)22.2 (16.1) mo	NR
Inoue et al[10] 2011	Japan	Retrospective, single center	137	Median (range) 70 (50–82)	Low, intermediate, high risk of D' Amico: 21%, 50%, 29%	Median (range) 7.2 (2.8–100)	13.1%	22.6%	Median (range) 36 (12–84) mo	1 session: 92.0%, 2 sessions: 8.0%, Mean:1.1 sessions
Komura et al[11] 2014	Japan	Retrospective, single center	171	Mean (SD) 68.3 (7.0)	Low, intermediate, high risk of D' Amico: 30.4%, 27.5%, 42.1%.	Median (IQR) 7.7 (5.8–12.6)	32.7%	44.4%	median (IQR): 43 (30–55) mo	NR
Maestroni et al[12] 2012	Italy	Retrospective, single center	74	Mean (rage) 72.7 (65–80)	Low, intermediate, high risk of D'Amico: 70%, 16,2%, 13.5%	Mean (SD) 8.07 (8.17)	68.9%	28.3%	Mean (range) 29.9 (9–40) Median 15 mo	NR
Mearini, et al[13] 2015	Italy	Prospective, single center	162	Median (IQR)72 (68–75)	Low, intermediate, high, very high risk of D' Amico: 49.1%, 28.8%, 8.6%, 13.5%	Median (IQR) 7.3 (5.2–10)	0	0	Median (IQR) 71.5 (66.1–73.2) mo	1 session: 82.8%, 2 sessions: 17.2%, Mean:1.17 sessions
Pinthus et al[14] 2012	Canada	Retrospective, single center	402	Mean (SD) 62.7 (7.5)	Low and intermediate risk of D' Amico: 45.5% and 54.5%	Mean (SD) 6.6 (3.1)	0	0	Median (range): 24 (6– 48) mo	Single
Pfeiffer et al[15] 2015	Germany	Retrospective, single center	327	Median (IQR) 70 (66.5–74.0)	Low, intermediate, high risk of D' Amico: 39.8%, 35.2%, 25.1%	Median (IQR) 7.1 (5.0–11.0)	80.7%	34.2%	Median (IQR) 51.2 (36.6–80.4) mo	NR
Ripert et al[16] 2011	Germany	Retrospective, single center	53	mean (range) 72.5 (60–79)	Low and intermediate risk of D' Amico: 52.8% and 47.2%.	Mean (SD, range) 8.5 (4.04, 0.29–18)	92.4%	0	Mean (SD) 45.4 (15.5) mo	NR

(*continued*)

Table 2
(continued).

Author	Country	Study design	Patients, no.	Age of patients	Risk classification	PSA (ng/mL)	TURP prior or combined with HIFU	ADT prior HIFU	Follow-up	More than 1 HIFU session
Sumitomo et al[17] 2008 HIFU only vs HIFU with NADT	Japan	Retrospective, 7 centers	260 vs 270	Mean (SD, range) 67.7 (7.2, 45–88) vs 68.2 (6.7, 52–85), Median (IQR)68.0 (63–73) vs 69.0 (64–73)	Low, intermediate, high risk of D' Amico: 93, 102, 65 vs 70, 113, 87	Median (IQR) 7.8 (6.2–11). Mean (SD, range) 9.1 (4.4, 2.3–29.4) vs 11.6 (6.2, 2.8–29.5)	NR	ADT within 6 mo	Mean (SD, range) 24 (12.4, 3–65) vs 22.9 (11.9, 2–61) mo, Median (IQR) 22 (15–30) vs 21 (14–29.8) mo	Mean (SD, range) 1.2 (0.46, 1–4) vs 1.23 (0.48, 1–3), Median (IQR) 1 (1–1) vs 1 (1–1)
Sung et al[18] 2012	Japan	Retrospective, single center	126	median (IQR) 71 (66–76)	Low, intermediate, high-risk of NCCN: 15.1%, 51.6%, 33.3%	Median (IQR) 8.7 (5.9–15.1)	88.9%	40.5%	Median (IQR): 61.1 (37.2–81.0) mo	NR
Thüroff et al[19] 2003	6 European sites	Prospective, 6 centers	402	Mean (SD) 69.3 (7.1) Median (IQR) 70 (65–75)	Low, intermediate, high risk: 28.4%, 48.0%, 23.6% Δ	Mean (SD)10.9 (8.7)	NR	NR	Mean 407.3 days, range 0–1541 d	Mean 1.47 sessions, 1 session: 62.4%, 2 sessions: 27.9%
Uchida et al[20] 2015	Japan	Retrospective	918	Median (IQR) 68 (46–88)	Low, intermediate, high risk of D' Amico: 25.6%, 44.1%, 30.3%.	Median (range) 8.57 (1.36–29.8)	14.9%	58.8%	Median (range) 78 (6–163) mo	Mean (SD) 1.3 (0.5)

Δ: Low risk = stage T1–2a and PSA ⩽10 ng/mL and Gleason score ⩽6; Intermediate risk = T2b or 10 < PSA > 20 ng/mL or Gleason score = 7; High risk = T2c or PSA > 20 ng/mL or Gleason score ⩾8.
NCCN = National Comprehensive Cancer Network, NR = not recorded, PSA = prostate-specific antigen.

Table 3

PSA nadir, OS, and meta-analysis of complications after HIFU.

Items	Whole-gland HIFU	Partial-gland HIFU	*P*-value
Minimum/maximum median nadir PSA (ng/mL)	0.03[11]/0.95 [12]	0.91[29]/4.2[28]	
Minimum/maximum mean nadir PSA (ng/mL)	0.4[8]/1.95 [16]	Whole-gland HIFU	
Minimum/maximum median time to PSA nadir (mo)	1.8[7]/3.7 [19]	NR	
Minimum/maximum mean time to PSA nadir (mo)	2.4[18]/5.4 [19]	5.7[27]/7.3[22]	
overall survival (OS)			
5-yr	90%,[4] 100% [11]	87%,[29] 97% [28]	
8-yr	83% [4]	97% [28]	
Incidences of Incontinence (%)	10%	2%	$P<.001$
Incidences of Impotence (%)	44%	21%	$P<.001$
Incidences of Urinary obstruction (%)	15%	2%	$P<.001$
Incidences of Urinary retention (%)	11%	9%	$P=.945$
Incidences of Urinary infection (%)	7%	11%	$P=.001$

HIFU = high-intensity focused ultrasound, NR = not recorded, PSA = prostate-specific antigen.

Only 1 study reported the incidence of urethrorectal fistula to be 2.6%.[22] The incidence of urethral structures was reportedly 0.9% to 4%,[24,25,27,29] and the rates of AUR and urinary infection were reported as 4.5% to 13.1%[22–24,27,29] and 5.6% to 17.6%,[23,24,27,29] respectively. Meta-analysis revealed the incidences of urinary obstruction, retention, and infection to be 2% (95% CI 0.00–0.034, $P=.01$), 9% (95% CI 0.00–0.12, $P<.00001$), and 11% (95% CI 0.05–0.17, $P=.00007$), respectively (Table 3 and Fig. 3).

4. Discussion

Data from RALP (robot-assisted laparoscopic prostatectomy) case series estimates the BCR-free survival rate to be 86.6% at 5 years after RALP.[30] The BDFS rate ranges from 77% to 88% at 5 years after whole-gland HIFU in 4 case series.[4,6,8,16] Although the overall and metastasis-free survival rates are not significantly different, the 5-year salvage-treatment free survival rate has been reported to be higher among patients undergoing HIFU compared with radical prostatectomy ($P<.01$).[31] In another matched-pair analysis, HIFU hemi-ablation was comparable to RALP in terms of controlling localized, unilateral PCa, with no significant differences in the need for salvage therapies.[32] While whole-gland HIFU offers comparable long-term efficacy for low-risk patients, the cancer control is thought to be insufficient for high-risk patients.[33] Therefore, there is a need for more prospective comparative studies, especially involving different risk subgroups in order to definitively evaluate the efficacy of HIFU treatment.

Our meta-analysis revealed the incidence of urinary incontinence and impotency after whole-gland HIFU (Table 3) to be lower than that of a recent prospective, controlled, non-randomized controlled trial (RCT) of patients in fourteen centers using RALP or retropubic prostatectomy (the rate of incontinence after RALP and retropubic radical prostatectomy to be 21.3%

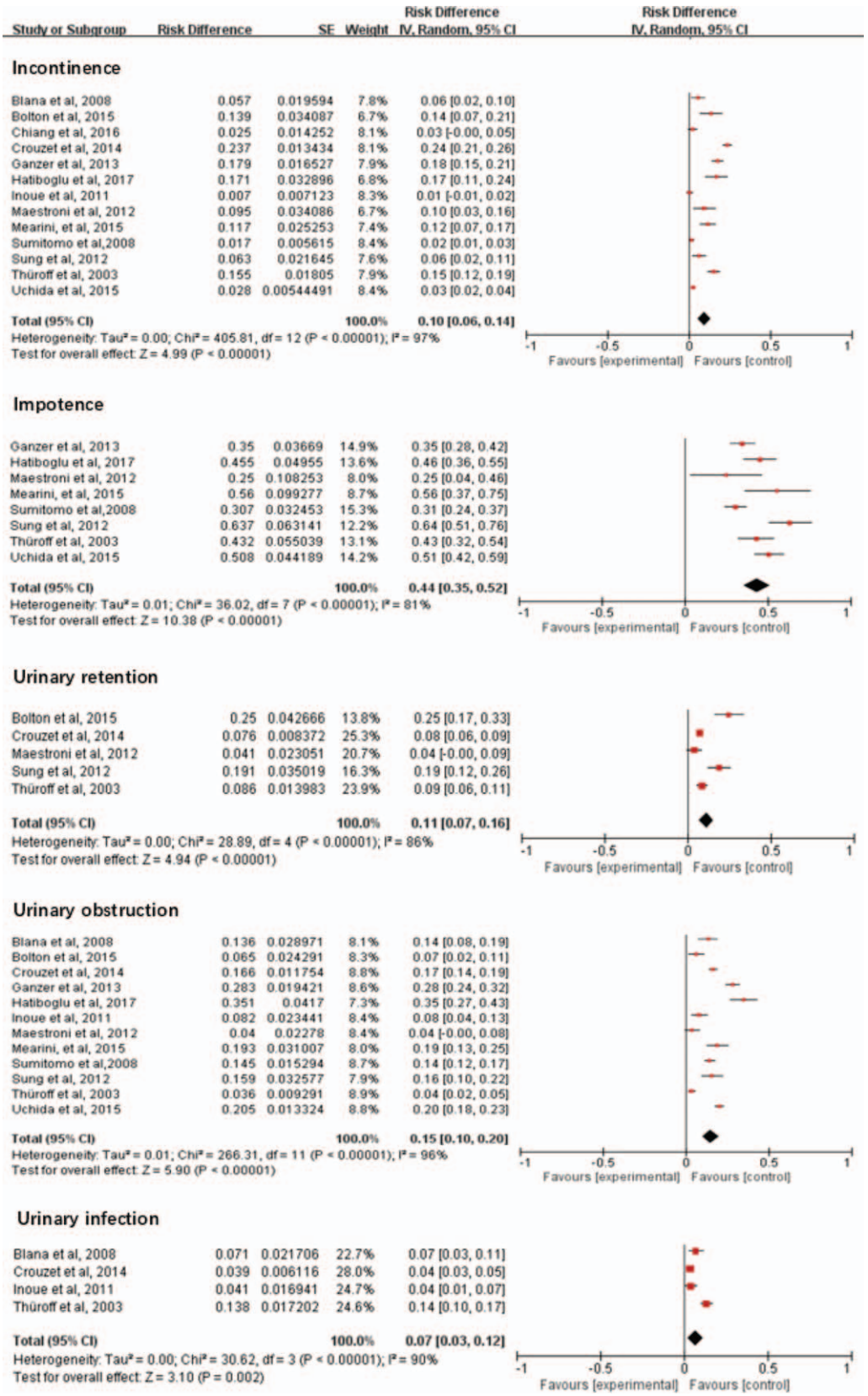

Figure 2. Forest plot for incidences of incontinence, impotence, urinary retention, urinary obstruction, urinary infection after whole-gland HIFU. HIFU = high-intensity focused ultrasound.

Table 4

Summary of studies of partial-gland high-intensity focused ultrasound.

Author	Country	Study design	Patients, no.	Age of patients	PSA (ng/mL)	Type of ablation % of patients	Follow-up	More than 1 HIFU session
Annoot et al[21] 2019	France	Retrospective, single center	55	Mean 63	Mean (SD) 6.18 (3.72–8.64)	Hemiablation	Mean (SD) 33 (17–49) mo	NR
Bass et al[22] 2019	Canada	Retrospective, 3 centers	150	Mean SD (range) 65.2 7.5 (45–80), Median (IQR) 65.0 (60–71)	Mean (SD, range) 7.7 (6.8, 0.7–66); Median (IQR) 6.4 (4.2–9)	Most patients received focal or hemiablation	Mean (SD) 24.3 (14.4) mo	Mean 1.11 sessions
Feijoo et al[23] 2016	France	Prospective, single center	67	Mean (SD) 70.2 (6.8)	Median (IQR) 6.1 (1.6–15.5)	Hemiablation	Median (IQR) 12 (6–50) mo	NR
Ganzer et al[24] 2018	Germany	Prospective, 5 centers	51	Mean (SD) 63.4 (8.3)	Mean (SD) 6.2 (2.1)	Hemiablation	Mean (SD, range) 17.4 (4.5, 12–24) mo	NR
Johnston et al[25] 2019	UK	Prospective, single center	107	Mean (range) 66 (47–81)	Mean (range) 7.7 (1.2–26.2)	Hemiablation: 50.5%, focal ablation: 9.3%, quadrant ablation: 40.2%	Median (range) 30 mo (12 mo–9 yr)	NR
Mortezavi et al[26] 2019	Switzerland	Prospective, single center	75	Median (IQR) 67 (60–71)	Median (IQR) 5.87 (4.65–7.44)	Focal ablation	NR	NR
Rischmann et al[27] 2017	France	Prospective, 10 centers	111	Mean (SD) 64.8 (6.2), Median (IQR) 64.9 (61–69)	Mean (SD) 6.2 (2.5) Median (IQR) 5.6 (4.7–7.6)	Hemiablation	Mean (SD) 30.4 (14.1) mo	NR
Stabile et al[28] 2019	UK	Retrospective, 2 centers	1032	Median (IQR) 65 (60–70)	Median (IQR) 7 (4.9–9.7)	Focal ablation: 71%, hemiablation: 29%	Median (IQR, range) 36 (14–64, 0–131) mo	NR
van Velthoven et al[29] 2016	Belgium	Prospective, single center	50	Mean (median, IQR)73 (74, 70–77)	Mean (median, range) 6.6 (6.3, 3.9–8.3)	Hemiablation	Mean (median, IQR) 39 (34, 13–58) mo	Mean 1.2 sessions

IQR = interquartile range, NR = not recorded, PSA = prostate-specific antigen, SD = standard deviation.

and 20.2%, respectively, and that of impotence to be 70.4% and 74.7%, respectively [34]). One of the studies reported that patients undergoing HIFU showed better short-term (6-month) continence outcomes (HIFU vs radical prostatectomy mean-international continence society questionnaire: 1.7 vs 4.8, $P = .005$),[31] and hemi-ablation HIFU has also been reported to be associated with significantly better functional outcomes compared with RALP (HIFU vs RALP continence at 1 month: 82% vs 40%, $P < .001$; potent at 1 month: 80% vs 15%, $P = .03$).[32]

Because active prostate tissue remains after partial ablation, the highest and lowest mean PSA nadir levels are higher than those following whole-gland ablation, and the time to PSA nadir is longer (Table 3). However, oncological outcomes of partial ablation have not been found to be worse than those of whole-gland ablation, especially among low- and intermediate-risk patients with PCa.[35,36] Partial ablation is associated with a reduced risk of complications than whole-gland ablation (Table 3), including urinary obstruction ($P < .001$), urinary incontinence ($P < .001$), and impotence ($P < .001$). This may be because the treatment time of partial ablation is shorter than that of whole-gland ablation, and the damage of periprostatic and pelvic floor tissue is reduced. These results suggest that partial-gland ablation is safer than whole-gland ablation, while oncological outcomes are not affected. However, there have been no prospective RCTs comparing whole-gland and partial-gland ablation.

The reason why the rate of positive biopsy following whole-gland ablation exhibits wide variation is due to the variety of reasons for repeat biopsy among the different studies. In some studies, repeat biopsy was routinely carried out after operation; in others, re-biopsy was only carried out in the case of considered BCR or suspected local recurrence from MRI. We did not perform meta-analysis of positive biopsy rate because of the different conditions for repeat biopsy.

The 8-year biochemical-free survival rates of patient who did and did not undergo ADT before HIFU were reportedly 70% and 66%, respectively,[7] while the 5-years BDFS rate did not differ significantly between such patients (83% and 78%, respectively).[8] The proportion of high-risk patients included in these 2 studies was less than 20%. Two studies[4,10] included patients with cancer classified as clinical stage T1-T2 (without T3, and without high-risk patients[4]), and reported no significant difference in terms of oncological outcomes between patients who did and did not undergo neoadjuvant ADT. Sumitomo et al[17] reported the median value of PSA nadir observed within 4 months after HIFU in the neoadjuvant ADT group was significantly lower than that in the HIFU-only group; the 3-year DFS rate among intermediate- or high-risk patients was significantly improved by combining neoadjuvant ADT. However, high-risk patients receiving ADT accounted for more than 30% of the population of this study, and pre-treatment PSA levels were higher among the neoadjuvant ADT than HIFU-only. Similarly, the population of the study of Uchida et al[20] included >30% high-risk patients, and the results showed that neoadjuvant ADT significantly influenced the incidence of biochemical failure. Therefore, the current clinical evidence indicates that patients with high-risk PCa can benefit from neoadjuvant ADT, while low-risk patients cannot benefit from this additional therapy.

The advantages of TURP before HIFU are

(1) reduction of prostate volume and required time for HIFU treatment;

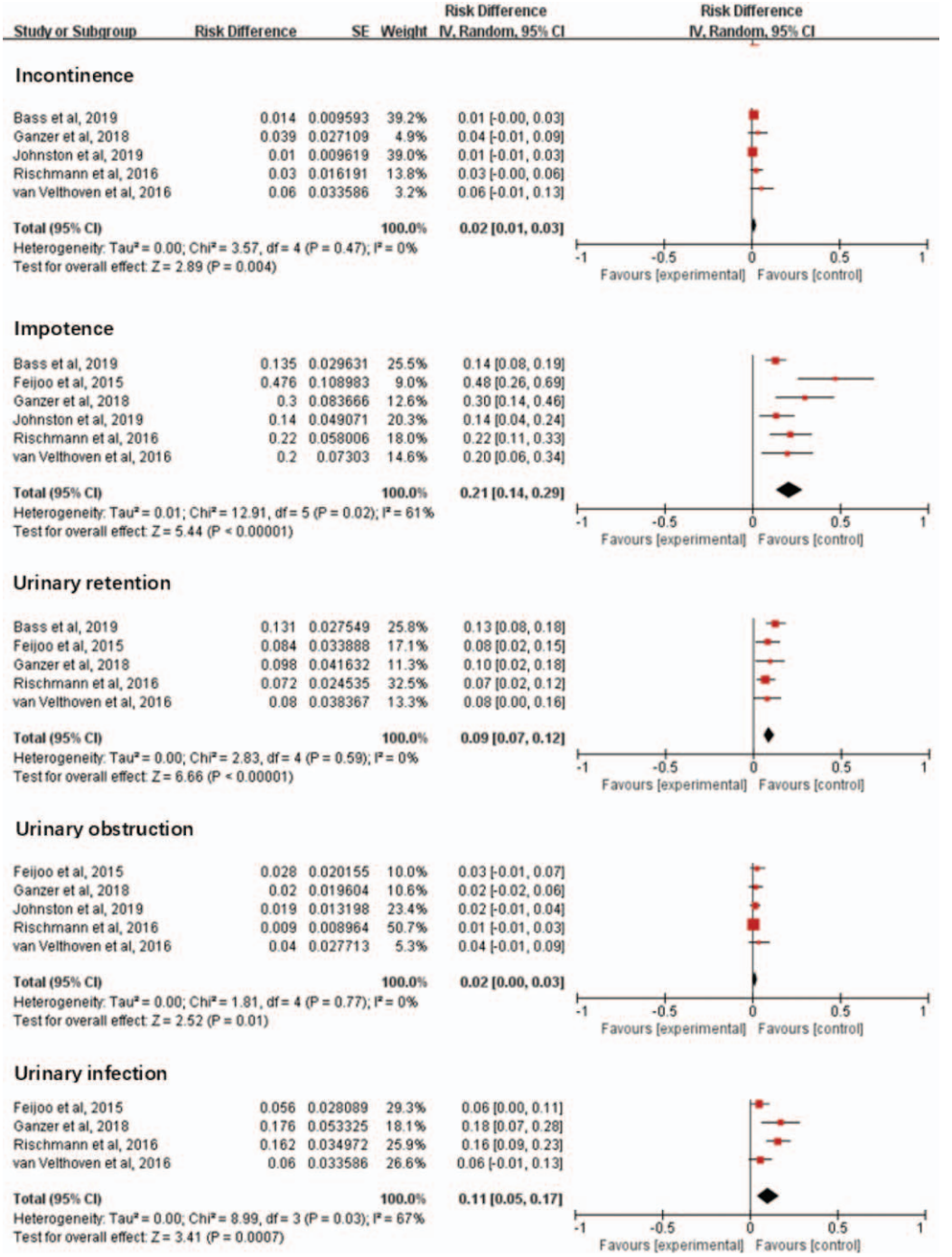

Figure 3. Forest plot for incidences of incontinence, impotence, urinary retention, urinary obstruction, urinary infection after partial-gland HIFU. HIFU = high-intensity focused ultrasound.

(2) removal of prostatic calcification or abscesses that could attenuate HIFU energy;
(3) reduction of the incidence of postoperative urinary obstruction and AUR.

Significant differences were not observed in biochemical-free survival rate between patients stratified according to the use or omission of preoperative TURP.[11] In partial-gland ablation, only 1 study reported the use of TURP before treatment (23.4%), the incidence of AUR in this study was the lowest of all reports.[27] Therefore, pre-treatment TURP may not affect oncological outcomes, but may reduce the risk of postoperative AUR.

One study reported a significant increase in the incidence of urinary incontinence with increased treatment times.[3] There was a statistically higher rate of BOO,[8] impotency,[37] and incontinence[37] among patients undergoing repeated HIFU compared with 1 HIFU session. The increased incidence of complications may be due to the increased HIFU energy reaching the prostate, which is required to eliminate residual tumors.[38] After treatment failure, redo-HIFU treatment can be selected, and

the advantages and disadvantages must be fully communicated with the patient.

5. Conclusion

HIFU can be considered to be superior to prostatectomy in terms of urinary and sexual outcomes. The partial-gland HIFU was safer than whole-gland HIFU, and they had similar oncological outcomes. Early evidence suggested patients with high-risk PCa can benefit from neoadjuvant ADT, while low-risk patients cannot benefit from this additional therapy; pre-treatment TURP may not affect oncological outcomes, but may reduce the risk of postoperative AUR.

To date, there have been no prospective RCTs comparing the outcomes of radical prostatectomy, radiation therapy, and HIFU. Furthermore, among the studies on partial-gland HIFU ablation, few have compared partial-gland treatment to whole-gland ablation. Those that do include such comparison are difficult to interpret given the absence of randomization. Therefore, more RCTs are needed investigating the benefits of HIFU for the treatment of PCa.

Author contributions

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Literature search and screening, data collection: Yue He, Ping Tan, Mingjing He
Project designation, public funding: Qiang Wei, Jianzhong Ai, Lu Yang

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