

BMJ Open Systematic bias between blinded independent central review and local assessment: literature review and analyses of 76 phase III randomised controlled trials in 45 688 patients with advanced solid tumour

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ABSTRACT

Objective Unbiased assessment of tumour response is crucial in randomised controlled trials (RCTs). Blinded independent central review is usually used as a supplemental or monitor to local assessment but is costly. The aim of this study is to investigate whether systematic bias existed in RCTs by comparing the treatment effects of efficacy endpoints between central and local assessments.

Design Literature review, pooling analysis and correlation analysis.

Data sources PubMed, from 1 January 2010 to 30 June 2017.

Eligibility criteria for selecting studies Eligible articles are phase III RCTs comparing anticancer agents for advanced solid tumours. Additionally, the articles should report objective response rate (ORR), disease control rate (DCR), progression-free survival (PFS) or time to progression (TTP); the treatment effect of these endpoints, OR or HR, should be based on central and local assessments.

Results Of 76 included trials involving 45 688 patients, 17 (22%) trials reported their endpoints with statistically inconsistent inferences (p value lower/higher than the probability of type I error) between central and local assessments; among them, 9 (53%) trials had statistically significant inference based on central assessment. Pooling analysis presented no systematic bias when comparing treatment effects of both assessments (ORR: OR=1.02 (95% CI 0.97 to 1.07), p=0.42, I²=0%; DCR: OR=0.97 (95% CI 0.92 to 1.03), p=0.32, I²=0%; PFS: HR=1.01 (95% CI 0.99 to 1.02), p=0.32, I²=0%; TTP: HR=1.04 (95% CI 0.95 to 1.14), p=0.37, I²=0%), regardless of funding source, mask, region, tumour type, study design, number of enrolled patients, response assessment criteria, primary endpoint and trials with statistically consistent/inconsistent inferences. Correlation analysis also presented no sign of systematic bias between central and local assessments (ORR, DCR, PFS: r>0.90, p<0.01; TTP: r=0.90, p=0.29).

Strengths and limitations of this study

- To our knowledge, this is the largest literature review and pooling analysis comparing treatment effects between blinded independent central review and local assessment in phase III randomised controlled trials on solid tumours.
- We performed an exhaustive literature search to include all potential studies fulfilling the inclusion criteria.
- We carefully extracted the data based on the independent and double-blind principle, in order to guarantee the accuracy of the data applied for further analysis.
- Compared with our study-level analysis, the analysis using individual patients' data could be more robust.
- For using trial data of both blinded independent central review and local assessment, the findings and conclusion of this research may not be generalisable for all phase III oncological randomised controlled trials, because the situation of either assessment could be unknown when trials did not implement or report both central and local assessments.

Conclusions No systematic bias could be found between local and central assessments in phase III RCTs on solid tumours. However, statistically inconsistent inferences could be made in many trials between both assessments.

INTRODUCTION

In phase III randomised controlled trials (RCTs), response-related or progression-related endpoints like objective response rate (ORR), disease control rate (DCR), progression-free survival (PFS) and time to

progression (TTP) are key for reflecting treatment effects of the experimental arm and the control arm for patients with advanced solid tumour.^{1–3} During trials, determination of tumour response should be assessed with accuracy, which is the prerequisite of implementation with standardised response assessment criteria (eg, Response Evaluation Criteria in Solid Tumors (RECIST) and WHO) as well.

Unlike overall survival, these endpoints assessed by local investigators are more influenced by subjective factors, including variability during tumour measurement, target lesion selection, failure to diagnose new lesions and different interpretations of non-target or immeasurable lesions.⁴ In open-label trials, the knowledge of investigators regarding treatment assignment could influence their assessment. Even in some double-blind trials, the investigators' knowledge may not be completely eliminated due to the adverse effects; for example, the investigators might be able to tell which treatments are assigned for their patients according to the different manifestations of treatments' adverse effects.⁵

Treatment effect is one of the main results considered for drug approval. If aforementioned subjective factors impact the assessment for trial endpoints, the subsequent result will overestimate or underestimate the true effect of treatments, which is called systematic bias.⁶ In order to detect potential bias from local investigators, blinded independent central review is requested by the regulatory authorities (eg, the US Food and Drug Administration (FDA)). During its implementation, all imaging examinations are reviewed by independent radiologists who are blinded to patients' treatment assignments and clinical information.⁷ However, this mechanism has some drawbacks. It increases the burden of time and expenditure on trials. Additionally, it may introduce missing data, information censoring and the neglect of symptomatic progression. These factors could result in different discrepancy rates of central and local assessments and sometimes among central reviewers themselves, which impacts treatment effects and may even cause potential bias.^{4,7,8}

Given the pros and cons of assessment by central reviewers, the FDA Oncology Drugs Advisory Committee discussed how to design a reliable assessment strategy for clinical trials with central review: if there is no strong evidence indicating systematic bias from two assessments, a sample-based central review could be considered in future usage instead of the complete assessment for all patients in the trials.⁹ This strategy may effectively reduce the complexity and implementation burden, without compromising the reliability of the RCTs.⁹

Accordingly, in order to understand the reliability of local assessment, as well as the necessity of central review, we conducted this literature review and analyses in order to investigate whether systematic bias existed in previous phase III RCTs on solid tumours.

METHOD

Search strategy and study selection

In accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement,¹⁰ a PubMed search was conducted by JRJ using the dates of 1 January 2010 to 30 June 2017. The search strategy is shown in online supplementary table 1. Inappropriate articles such as reviews, systematic reviews and/or meta analyses, guidelines and commentaries were excluded.

Eligible trials were those directly evaluating therapeutic efficacy of anticancer agents in phase III RCTs for patients with advanced solid tumour; additionally, the imaging assessment for tumour response or progression was conducted by both central reviewers and local investigators. As some authors reported their data in more than one article, we used the name and/or National Clinical Trial (NCT) number of eligible RCTs as search terms to re-search PubMed (without the time interval limitation), to find out if there were more available articles on those RCTs. Endnote X7 (Thomson Reuters, New York City, New York, USA) was used in the above process.

Data extraction

The process of data extraction was carried out independently and double-blindly by three reviewers (JRJ with YYZ and SYT; in blocks of 50 articles allocated at random; discrepancies were resolved by WHL). To ensure consistency between reviewers, we used the same data extraction form, piloted the data extraction by using a sample of 16 included trials and had discussions before and during the extraction process to confer how to properly extract and interpret the data.

The following characteristics of each trial were extracted: author, year, NCT number, funding source (pharmaceutical or academic), mask (open label, single blind or double blind), region (global or intracontinental), tumour type (eg, breast cancer, ovarian cancer, melanoma), study design (superiority, non-inferiority or hybrid; hybrid design includes the design of superiority and non-inferiority), number of enrolled patients, response assessment criteria (RECIST or WHO), primary endpoint (central assessed, local assessed or other) and the statistical inference of the primary endpoint according to whether the p value was lower than the probability of the type I error (positive, negative or indeterminate). We also extracted estimated treatment effects from both central and local assessments, including the OR of experimental arm ORR to control arm ORR, OR of experimental arm DCR to control arm DCR, HR of experimental arm PFS to control arm PFS, and HR of experimental arm TTP to control arm TTP. Regarding overlapped data from more than one article on one trial, we selected data based on primarily larger analysis or recently updated analysis. For PFS and TTP, if both intention to treat (or other methods with a larger population) and per-protocol population were available for trials' treatment effects, we preferred the former in our

research. According to characteristics, the risk of bias was evaluated in each trial (online supplementary efigure 1).

Statistical analysis

First, we investigated whether there were trials with statistically inconsistent inferences between two assessments in primary and secondary endpoints (including ORR, PFS and TTP). If these trials could be identified, we calculated the percentage of these trials among all our eligible trials. Statistically inconsistent inferences are defined as the treatment effect from one of the assessments (eg, central assessment) indicating significant difference (p value is lower than the probability of the type I error or the confidence interval of the treatment effect does not cross 1), but the treatment effect from another assessment (eg, local assessment) indicating non-significant difference (p value is higher than the probability of the type I error, or the confidence interval of the treatment effect crosses 1).

Furthermore, to statistically investigate whether systematic bias existed, we made a comparison of treatment effects between central and local assessments, by conducting a pooling analysis with the inverse variance method and fixed-effect model in Review Manager 5.3 (The Cochrane Collaboration, London, England). In this process, if the corresponding p value for heterogeneity was less than 0.05 or the I^2 index was over 50%, we used a random-effect model instead of the fixed-effect model in order to reduce the effect of heterogeneity. The pooled OR and HR were the measure of this comparison, expressed as the ratio of central-assessed treatment effects (eg, OR of ORR, OR of DCR, HR of PFS, HR of TTP) to local-assessed treatment effects.¹¹ The OR (of ORR or DCR) greater than 1 indicated that central review overestimated the efficacy of the therapeutic strategy in the experimental arm; while a HR (of PFS or TTP) greater than 1 indicated that central review underestimated the therapeutic efficacy of the experimental arm (compared with local assessment). Regardless of whether the ratio was higher or lower than 1, we concluded no sign of a significant systematic bias if: (1) the corresponding p value was higher than 0.05, which means the 95% CI of the pooled ratio (HR, OR) crossed 1; (2) the 95% CI of the pooled ratio was extremely tight (<5%) if the first consideration was not met. For the above summary synthesis of ORR, DCR, PFS and TTP, a funnel plot was used to estimate publication bias (online supplementary efigure 2). Furthermore, we conducted subgroup analysis based on the trial characteristics: funding source, mask, region, trial design, number of enrolled patients (based on median value of all included trials), tumour type, response assessment criteria, primary endpoint and its outcome, as well as statistical inferences between central and local assessments (consistent/inconsistent).

In order to verify the result of the pooling analysis, we conducted correlation analysis for the treatment effects between central and local assessments, by using SPSS V.23 (SPSS, Chicago, Illinois, USA). The test for normality was completed first, followed by correlation analysis with a

bivariate model: if normal distribution was indicated, we estimated the correlation by the Pearson correlation coefficient; if not, the Spearman's correlation was applied. Significant correlation was indicated when the p value was less than 0.05. The correlation between two assessments was also demonstrated in scatterplots, constructed by using Excel 2011 (Microsoft, Seattle, Washington, USA).

Patient and public involvement

Due to the nature of the literature review, we do not have patient and public involvement in this research.

RESULTS

Trial searching and characteristics

Based on article identification and selection (figure 1), we included a total of 76 trials from 100 articles, involving 45 688 randomly assigned patients.^{12–111}

Summary and detailed characteristics are presented in table 1 and in online supplementary efigure 2. A majority of the 100 articles were published in high-impact journals: *Journal of Clinical Oncology* (29), *Lancet Oncology* (24), *New England Journal of Medicine* (18), *Lancet* (10), *European Journal of Cancer* (4), *Gynecologic Oncology* (4), *Annals of Oncology* (3), *Oncologist* (3) and so on. In all 76 included trials, 15 trials^{13–17 26 27 30 31 41 48 64 67 68 90 97 101 105 109 110} reported both central-assessed and local-assessed treatment effects of ORR and DCR; among them, 14 trials^{13–17 26 27 30 31 41 64 67 68 90 97 101 105 109 110} had those of ORR, DCR and PFS, including one trial⁶⁸ with those of ORR, DCR, PFS and TTP. Another 12 trials^{18 28 29 33 37 51 57 65 79 84 85 91 92 103} with both central and local assessments only contained treatment effects of ORR and PFS.

Statistical analysis

Statistically inconsistent inferences of central and local assessments

From a total of 76 included trials, 17 trials (22%) had statistically inconsistent inferences (significant difference/non-significant difference) of ORR, PFS and/or TTP between central and local assessments.^{17 29 33 48 57 66 68 69 79 87 97 105 110} Among these 17 trials, 2 trials^{29 33} had inconsistent inferences in both of the primary endpoint and secondary endpoint simultaneously. In total, there were 9 of 17 trials (53%) with significant difference based on central assessment; 5 (56%) of these 9 trials were on open-label design (table 2).

Systematic bias between central and local assessments

All comparison results of pooling analysis are presented at table 3. There was no significant difference in the treatment effects of ORR between central and local assessments (OR: 1.02 (95% CI 0.97 to 1.07), p=0.42; heterogeneity: p=0.91, $I^2=0\%$; online supplementary efigure 3). Similarly, no sign of significant difference was in DCR (OR: 0.97 (95% CI 0.92 to 1.03), p=0.32; heterogeneity: p=0.93, $I^2=0\%$; online supplementary efigure 4), PFS (HR: 1.01 (95% CI 0.99 to 1.02), p=0.32; heterogeneity: p=1.00,

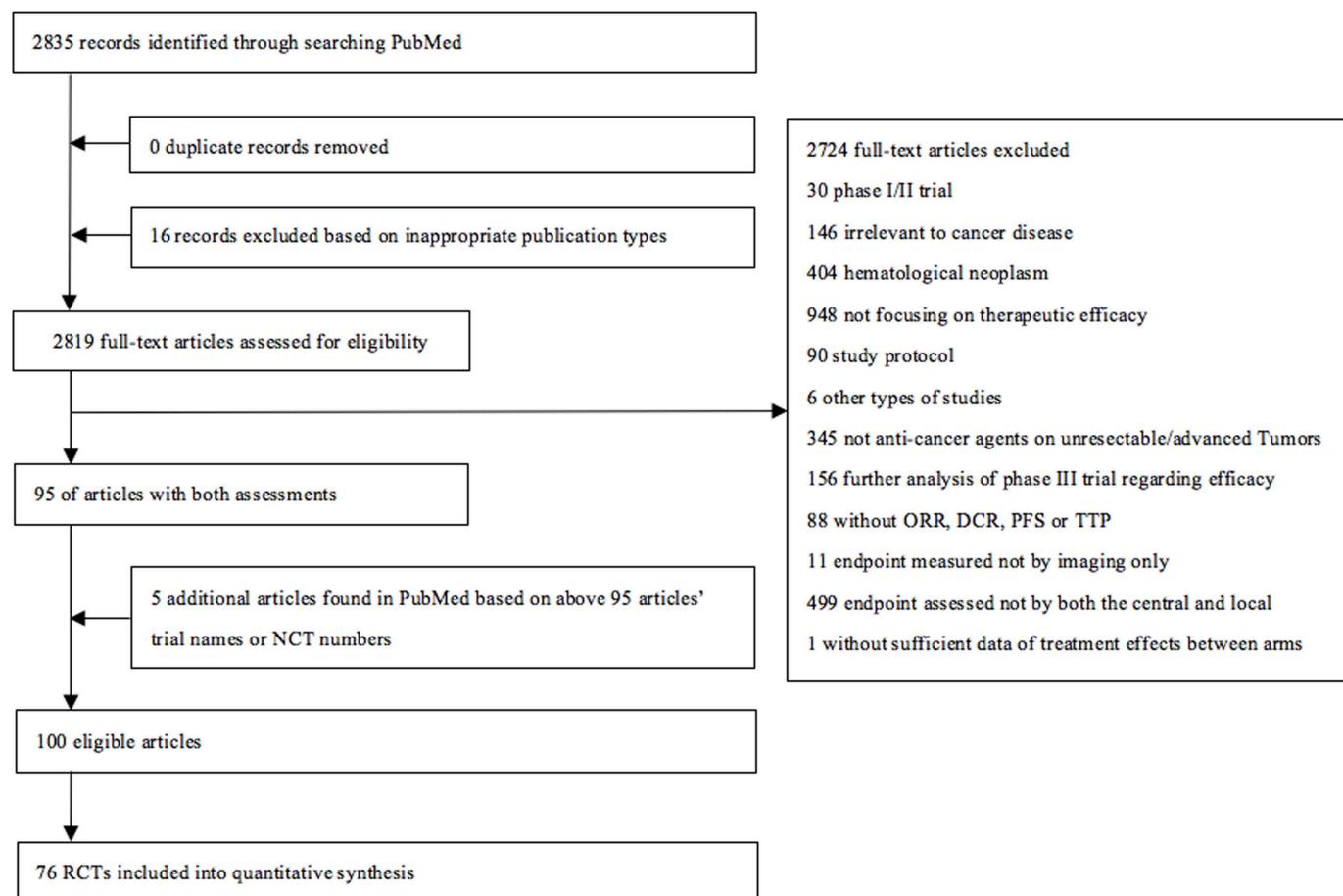


Figure 1 Flow chart of study identification and selection. DCR, disease control rate; NCT, National Clinical Trial; ORR, objective response rate; PFS, progression-free survival; RCT, randomised controlled trial; TTP, time to progression.

$I^2=0\%$; online supplementary efigure 5) and TTP (HR: 1.04 (95% CI 0.95 to 1.14), $p=0.37$; heterogeneity: $p=0.59$, $I^2=0\%$; online supplementary efigure 6). Subgroup analysis also presented no significant difference between central and local assessments, and no significant interaction effect between different elements of subgroup factors, including open label or blind design (table 3).

The strength of the correlation between central and local assessments regarding treatment effect of ORR, DCR, PFS and TTP was 0.91 ($p<0.01$), 0.93 ($p<0.01$), 0.94 ($p<0.01$) and 0.90 ($p=0.29$), respectively (figure 2).

DISCUSSION

To our knowledge, this is the largest literature review with data analyses investigating blinded independent central review and local assessment in phase III RCTs on solid tumours. Also, it is the first research article to report the statistically inconsistent inferences (significant difference or not) of primary and secondary endpoints assessed by central reviewers and local investigators. We found 22% of trials (17/76) with inconsistent inferences between central and local assessments. However, our subsequent pooling analysis and correlation analysis based on all 76 trials confirmed no sign of systematic bias between central and local assessments, regardless of funding source, mask,

region, tumour type, study design, number of enrolled patients, response assessment criteria, primary endpoint and outcome, as well as trials with statistically consistent/inconsistent inferences.

Blinded independent central review is used to detect potential bias introduced by the assessment of local investigators. This consideration is based on a common assumption that local investigators might expect superior efficacy of experimental arm treatments compared with control arm treatments, especially in trials with open-label design. Interestingly, among the 17 trials with statistically inconsistent inferences between central and local assessments, more than half of those 17 studies (9/17; 53%) had a statistically significant difference in central assessment; in these 9 trials, 5 (56%) trials were based on open-label design. This means that central assessment seems to have more positive outcomes in favour of experimental treatments in an open-label design, which contradicts the above common assumption.

With respect to statistically inconsistent inferences between central and local assessments, we assume evaluation variability is one factor accounting for these. As we understand, variability could be impacted by many subjective factors, causing measurement errors or uncertainty.⁸ This situation occurs when one scan reviewer assesses the

Table 1 Summary characteristics of included trials

Characteristics	Trial(s) (n=76)	Patients (n=45688)
Fund source		
Pharmaceutical	73	43 557
Academic	3	2131
Mask		
Open label	37	21 455
Single blind	1	185
Double blind	38	24 048
Region		
Global	62	39 766
Intracontinental	14	5922
Design		
Superiority	71	42 213
Other*	5	3475
Number of enrolled patients		
Maximum	–	1314
Median	–	542
Minimum	–	81
Tumour type		
Breast cancer	17	11 132
NSCLC	14	9327
Renal cell carcinoma	11	6720
Ovarian cancer	6	4536
Melanoma	5	1675
Other†	23	12 298
Response assessment criteria		
RECIST	71	42 756
WHO	4	2387
Not given	1	545
Primary endpoint		
Central assessed‡	43	26 344
Other§	10	6177
Local assessed¶	23	13 167
Primary endpoint outcome		
Positive	51	29 982
Indeterminate**††	2	1106
Negative	23	14 600

*Four non-inferiority, one hybrid design combining superiority and non-inferiority.

†Four gastrointestinal stromal tumour, three pancreatic tumour, three sarcoma, three medullary thyroid cancer, two glioblastoma, two prostate cancer, two neuroendocrine tumour, one colorectal adenocarcinoma, one gastric cancer, one head and neck cancer and one hepatocellular carcinoma.

‡Forty central-assessed PFS, two central-assessed time to progression and one central-assessed ORR.

§Nine overall survival and one unknown-assessed ORR.

¶Twenty-three local-assessed PFS.

**One study used ORR as the primary endpoint, but we were unable to recognise which assessment (central or local assessment) for the ORR was considered as the primary endpoint (central-assessed ORR or local-assessed ORR?). Because a significant difference was found in central review ($p=0.03$) but not found in local assessment ($p=0.05$), we considered the outcome of the primary endpoint as indeterminate.⁴⁸

††Another study considered local-assessed PFS and OS as coprimary endpoints: a significant difference was found in PFS ($p<0.01$), but was not found in OS ($p=0.10$). We considered the outcome of the primary endpoint as indeterminate as well.⁸³

NSCLC, non-small-cell lung cancer; ORR, objective response rate; OS, overall survival; PFS, progression-free survival; RECIST, Response Evaluation Criteria in Solid Tumors.

Table 2 Trials with statistically inconsistent inferences between central and local assessments

Trial	Endpoint	Mask	Tumour type	Therapy (experimental arm vs control arm)	HR/OR and p value
Primary endpoint					
NCT00019682 ⁴⁸	ORR	Single	Melanoma	Exp: gp100:209-217(210M)+Montanide ISA-51 +interleukin 2 Con: Interleukin 2	Central: 2.86 (95% CI 1.05 to 7.82); p=0.03 Local: 2.33 (95% CI 0.98 to 5.56); p=0.05
NCT00471328 ⁶⁶	Central PFS	Open	Gastrointestinal stromal tumour	Exp: Nilotinib Con: Best supportive care/BSC+imatinib/BSC+sunitinib	Central: 0.90 (95% CI 0.65 to 1.26); p=0.56 Local: 0.58 (95% CI 0.42 to 0.80); p<0.01
NCT00112294 ³³	Central PFS	Open	Non-small-cell lung cancer	Exp: Cetuximab+taxane (paclitaxel/docetaxel)+carboplatin Con: Taxane (paclitaxel/docetaxel)+carboplatin	Central: 0.90 (95% CI 0.76 to 1.07); p=0.24 Local: 0.79 (95% CI 0.67 to 0.93); p<0.01
NCT00703326 ⁶⁹	Local PFS	Double	Breast cancer	Exp: Ramucirumab+docetaxel Con: Placebo+docetaxel	Central: 0.79 (95% CI 0.67 to 0.94); p<0.01 Local: 0.88 (95% CI 0.75 to 1.01); p=0.08
NCT00391092 ²⁹	Local PFS	Open	Breast cancer	Exp: Bevacizumab+docetaxel+trastuzumab Con: Docetaxel+trastuzumab	Central: 0.72 (95% CI 0.54 to 0.94); p=0.02 Local: 0.82 (95% CI 0.65 to 1.02); p=0.08
NCT00494299 ⁸⁷	Central TTP	Double	Hepatocellular carcinoma	Exp: Sorafenib Con: Placebo	Central: 0.87 (95% CI 0.70 to 1.09); p=0.25 Local: 0.79 (95% CI 0.62 to 1.00); p=0.049
NCT01007942 ¹²	Local PFS	Double	Breast cancer	Exp: Everolimus+trastuzumab+vinorelbine Con: Placebo+trastuzumab+vinorelbine	Central: 0.88 (95% CI 0.71 to 1.07); p=NG Local: 0.78 (95% CI 0.65 to 0.95); p<0.01
NCT01584648 ^{34 35}	Local PFS	Double	Melanoma	Exp: Trametinib+dabrafenib Con: Placebo+dabrafenib	Central: 0.78 (95% CI 0.59 to 1.04); p=NG Local: 0.75 (95% CI 0.57 to 0.99); p=0.03
NCT00412061 ⁴⁴	Central PFS	Double	Neuroendocrine tumour	Exp: Everolimus+octreotide Con: Placebo+octreotide	Central: 0.77 (95% CI 0.59 to 1.00); p=0.03* Local: 0.78 (95% CI 0.62 to 0.98); p=0.02*

Continued

Table 2 Continued

Trial	Endpoint	Mask	Tumour type	Therapy (experimental arm vs control arm)	HR/OR and p value
NCT00056459 ⁷⁶	Central PFS	Double	Colorectal adenocarcinoma	Exp: Vatalanib+oxaliplatin+fluorouracil+leucovorin Con: Placebo+oxaliplatin+fluorouracil+leucovorin	Central: 0.88 (95% CI 0.74 to 1.03); p=0.12 Local: 0.83 (95% CI 0.70 to 0.98); p=0.03
Secondary endpoint					
NCT00391092 ²⁹	ORR	Open	Breast cancer	Exp: Bevacizumab+docetaxel+trastuzumab Con: Docetaxel+trastuzumab	Central: 1.66 (95% CI 1.08 to 2.54); p=0.02 Local: 1.25 (95% CI 0.82 to 1.92); p=0.30
NCT00112294 ³³	ORR	Open	Non-small-cell lung cancer	Exp: Cetuximab+taxane(paclitaxel/docetaxel)+carboplatin Con: Taxane(paclitaxel/docetaxel)+carboplatin	Central: 1.67 (95% CI 1.15 to 2.43); p=0.01 Local: 1.31 (95% CI 0.92 to 1.86); p=0.13
NCT00720941 ⁵⁷	ORR	Open	Renal cell carcinoma	Exp: Pazopanib Con: Sunitinib	Central: 1.35 (95% CI 1.03 to 1.75); p=0.03 Local: 1.23 (95% CI 0.95 to 1.59); p=0.11
NCT01030783 ⁷⁹	ORR	Open	Renal cell carcinoma	Exp: Tivozanib Con: Sorafenib	Central: 1.62 (95% CI 1.10 to 2.39); p=0.01 Local: 1.23 (95% CI 0.85 to 1.78); p=0.26
NCT01523587 ⁹⁷	ORR	Open	Non-small-cell lung cancer	Exp: Afatinib Con: Erlotinib	Central: 2.05 (95% CI 0.98 to 4.29); p=0.06 Local: 2.88 (95% CI 1.60 to 5.21); p<0.01
NCT01345682 ¹⁰⁵	ORR	Open	Head and neck cancer	Exp: Afatinib Con: Methotrexate	Central: 1.90 (95% CI 0.88 to 4.14); p=0.10 Local: 3.00 (95% CI 1.3–6.9); p=0.01
NCT00785785 ¹¹⁰	ORR	Open	Gastrointestinal stromal tumour	Exp: Nilotinib Con: Imatinib	Central: 0.71 (95% CI 0.52 to 0.96); p=0.03 Local: 0.78 (95% CI 0.57 to 1.06); p=0.12
NCT00388726 ¹⁷	PFS	Open	Breast cancer	Exp: Eribulin Con: Treatment of physician's choice†	Central: 0.87 (95% CI 0.71 to 1.05); p=0.14 Local: 0.76 (95% CI 0.64 to 0.90); p<0.01

Continued

Table 2 Continued

Trial	Endpoint	Mask	Tumour type	Therapy (experimental arm vs control arm)	HR/OR and p value
NCT00449033 ⁶⁸	PFS	Double	Non-small-cell lung cancer	Exp: Sorafenib+gemcitabine+cisplatin	Central: 0.96 (95% CI 0.77 to 1.21); p=0.37*
				Con: Placebo+gemcitabine+cisplatin	Local: 0.83 (95% CI 0.71 to 0.97); p<0.01*
	TTP				Central: 0.91 (95% CI 0.67 to 1.23); p=0.26*
					Local: 0.73 (95% CI 0.60 to 0.88); p<0.01*

*One side.

†Any single-agent chemotherapy or hormonal or biological treatment approved for the treatment of cancer.

BSC, best supportive care; central, central assessed; Con, control arm; Double, double blind; Exp, experimental arm; Local, local assessed; NG, not given; Open, open label; ORR, objective response rate; PFS, progression-free survival; Single, single blind; TTP, time to progression.

response status of different individual patients, as well as when several reviewers conduct the scan assessment for one trial, regardless of whether this is a central or local assessment. In this situation, the evaluation variability attenuates the treatment effect and reduces the statistical power of the clinical trials.⁶⁸ This understanding has been verified based on 21 phase III cancer trials, demonstrating large variability but no sign of systematic bias between two assessments.¹¹²

Missing data could be another factor. It occurs when some patients do not have complete follow-up to determine progression or death, or when patients stop receiving randomised treatments or use alternative treatments before they have progression.¹¹³ In oncological clinical trials, missing data are regarded as censoring. Similar to evaluation variability, the effect of censoring would not contribute to systematic bias but could attenuate the treatment effect.¹¹³

In the trials included in our study, we consider that evaluation variability, censoring and other unmentioned factors simultaneously played a role in attenuating the treatment effects, resulting in statistically inconsistent inferences between two assessments in 17 of the 76 trials. Whereas, regardless of what causes statistically inconsistent inferences, the robustness of the trial efficacy outcome needs to be carefully considered when two assessments present statistically inconsistent inferences, especially in primary endpoint. Even though this inconsistency is unnecessary to reflect a systematic bias, it would be interesting to know how policy-makers consider the approval process for corresponding anticancer agents to the specific patients with cancer.

Considering statistically inconsistent inferences, we believe that blinded independent central review is still a useful method for controlling the risk of bias from local assessment. However, we also question the necessity of central assessment as a routine assessment method for all patients (complete-case fashion) in clinical trials. According to our research, there was no sign of systematic bias: (1) the 95% CIs of all pooled ratios in ORR, DCR, PFS and TTP crossed 1, indicating non-significant difference of the treatment effects between central and local assessments; (2) the 95% CIs were tight as well (especially in PFS), representing quite a precise estimate of the bias that should be negligible. These findings could be further confirmed by our subgroup analysis, even though a small number of the intervals are too wide to be informative due to a limited number of the trials (eg, only one trial used single blind, the OR of ORR was 1.09 (95% CI 0.61 to 1.95)).

When questioning the necessity of the complete central assessment, its drawbacks should be considered as well. First, its implementation in the complete-case fashion is very costly. Second, technically it is hard to conduct a real-time central assessment along with local assessment, to determine disease progression independently. In other words, the decision of central reviewers could be impacted by local investigators when the local

Table 3 Summary results of comparing treatment effects between central and local assessments

Summary/subgroup	Objective response rate (ORR)				Disease control rate				Progression-free survival						
	Study (n)	Patient (n)	OR (95%CI)	P values* I ² †‡	Study (n)	Patient (n)	OR (95%CI)	P values* I ² †‡	Study (n)	Patient (n)	HR (95%CI)	P values* I ² †‡			
Summary	29	17949	1.02 (0.97 to 1.07)	0.42	0%	15	9590	0.97 (0.92 to 1.03)	0.32	0%	43695	1.01 (0.99 to 1.02)	0.32	0%	
Funding source															
Pharmaceutical	28	17764	1.02 (0.97 to 1.07)	0.43	0%	14	9405	0.97 (0.92 to 1.03)	0.33	0%	41749	1.01 (0.99 to 1.02)	0.38	0%	
Academic	1	185	1.09 (0.61 to 1.95)	0.76		1	185	0.98 (0.67 to 1.42)	0.91		3	1946	1.03 (0.95 to 1.11)	0.50	
Mask															
Open label	23	14616	1.03 (0.98 to 1.09)	0.23	0%	12	7777	0.96 (0.91 to 1.02)	0.23	0%	36	20403	1.01 (0.99 to 1.04)	0.13	0%
Single blind	1	185	1.09 (0.61 to 1.95)	0.76		1	185	0.98 (0.67 to 1.42)	0.91		–	–	–	–	
Double blind	5	3148	0.95 (0.83 to 1.08)	0.41		2	1628	1.02 (0.89 to 1.17)	0.77		36	23292	1.00 (0.98 to 1.02)	0.93	
Region															
Global	23	15384	1.01 (0.95 to 1.06)	0.81	24%	12	8636	0.96 (0.91 to 1.02)	0.20	37%	61	38714	1.01 (0.99 to 1.02)	0.37	0%
Intracontinental	6	2565	1.08 (0.97 to 1.21)	0.17		3	954	1.11 (0.90 to 1.36)	0.34		11	4981	1.01 (0.97 to 1.05)	0.68	
Trial design															
Superiority	27	15787	1.02 (0.97 to 1.08)	0.48	0%	15	9590	0.97 (0.92 to 1.03)	0.32	–	69	41570	1.01 (0.99 to 1.02)	0.34	–
Other§	2	2162	1.03 (0.91 to 1.15)	0.67		–	–	–	–		3	2125	1.01 (0.95 to 1.07)	0.79	
Number of enrolled patients															
>542	17	13260	1.00 (0.94 to 1.06)	0.94	11%	10	7711	0.97 (0.91 to 1.03)	0.26	0%	37	30493	1.01 (0.99 to 1.03)	0.40	0%
<542	12	4689	1.06 (0.97 to 1.16)	0.18		5	1879	1.01 (0.88 to 1.15)	0.93		35	13202	1.01 (0.98 to 1.04)	0.60	
Tumour type															
Breast cancer	6	4028	1.08 (0.97 to 1.21)	0.18	0%	5	3435	0.97 (0.88 to 1.07)	0.58	0%	15	10410	1.00 (0.97 to 1.03)	0.88	0%
NSCLC	8	5172	1.01 (0.93 to 1.11)	0.80		3	2063	1.01 (0.89 to 1.13)	0.91		13	8275	1.02 (0.99 to 1.06)	0.19	
Renal cell carcinoma	6	3917	1.01 (0.91 to 1.12)	0.81		3	1951	0.95 (0.84 to 1.08)	0.43		11	6720	1.00 (0.96 to 1.04)	0.87	
Ovarian cancer	3	1985	0.98 (0.85 to 1.12)	0.72		1	829	0.92 (0.78 to 1.08)	0.31		6	4536	1.03 (0.99 to 1.09)	0.17	
Melanoma	2	435	1.35 (0.91 to 2.00)	0.14		1	185	0.98 (0.67 to 1.42)	0.91		4	1490	1.02 (0.92 to 1.12)	0.74	
Others¶	4	2412	0.99 (0.87 to 1.12)	0.83		2	1127	1.00 (0.84 to 1.19)	1.00		23	12264	1.00 (0.97 to 1.03)	0.94	
Response assessment criteria															
RECIST	27	17088	1.02 (0.97 to 1.07)	0.55	0%	14	9405	0.97 (0.92 to 1.03)	0.33	0%	68	40948	1.01 (0.99 to 1.02)	0.41	0%
WHO	2	861	1.11 (0.90 to 1.37)	0.33		1	185	0.98 (0.67 to 1.42)	0.91		3	2202	1.02 (0.97 to 1.08)	0.44	
Not given	–	–	–	–		–	–	–	–		1	545	1.00 (0.88 to 1.33)	0.94	
Primary endpoint															
Central assessed	17	11151	1.04 (0.98 to 1.10)	0.23	47%	10	6186	0.97 (0.90 to 1.04)	0.37	0%	40	24536	1.01 (0.99 to 1.03)	0.44	0%
Others**	7	4465	0.93 (0.83 to 1.04)	0.19		4	2680	0.98 (0.88 to 1.08)	0.65		9	5992	1.02 (0.98 to 1.07)	0.26	
Local assessed	5	2333	1.08 (0.94 to 1.24)	0.27		1	724	0.99 (0.79 to 1.24)	0.95		23	13167	1.00 (0.97 to 1.03)	0.96	

Continued

Table 3 Continued

Summary/subgroup	Objective response rate (ORR)			Disease control rate			Progression-free survival		
	Study (n)	Patient (n)	OR (95% CI)	P values* I ² †	Study (n)	Patient (n)	OR (95% CI)	Patient (n)	P values* I ² †
Primary endpoint outcome									
Positive	19	11 811	1.04 (0.98 to 1.11)	0.24	9	5484	0.99 (0.91 to 1.06)	28 930	1.00 (0.99 to 1.02) 0.63
Indeterminate	1	185	1.09 (0.61 to 1.95)	0.76	1	185	0.98 (0.67 to 1.42)	921	0.98 (0.89 to 1.07) 0.65
Negative	9	5953	0.99 (0.92 to 1.07)	0.86	5	3921	0.95 (0.88 to 1.04)	13 844	1.02 (0.99 to 1.04) 0.24
Statistical inferences between central and local assessments									
Consistent	18	10 726	1.02 (0.96 to 1.09)	0.53	8	5094	0.95 (0.88 to 1.03)	32 676	1.00 (0.99 to 1.02) 0.69
Inconsistent	11	7223	1.02 (0.95 to 1.10)	0.60	7	4496	0.99 (0.92 to 1.08)	11 019	1.02 (0.99 to 1.05) 0.20

*P value for the comparison between central and local assessments.

†I² in summary outcome was for heterogeneity of data synthesis.

‡I² in subgroup was for subgroup difference, representing the interaction effects between the elements of each subgroup factor.

\$Four non-inferiority, one hybrid design combining superiority and non-inferiority.

¶Four gastrointestinal stromal tumour, three pancreatic tumour, three sarcoma, three medullary thyroid cancer, two glioblastoma, two prostate cancer, two neuroendocrine tumour, one colorectal adenocarcinoma, one gastric cancer, one head and neck cancer and one hepatocellular carcinoma.

**Nine overall survival and one unknown-assessed ORR.

RECIST, Response Evaluation Criteria in Solid Tumors.

investigators declare progression, and 'progressed' patients may start to receive subsequent-line treatments. Therefore, the progression time of these specific patients is unknown for central reviewers, which is called informative censoring.^{5 69 111 112} Third, based only on imaging information, central reviewers could not conclude progression when patients have symptomatic deterioration. Both information censoring and withdrawal of patients with symptomatic progression (because of no radiological progression in central assessment) may potentially cause bias when the final treatment effects of the experimental arm to the control arm in RCTs are calculated.^{5 8 114}

Fourth, similar to local assessment, central assessment also shares some drawbacks, such as evaluation variability, target-lesion selection and different interpretations on non-target or immeasurable lesions.⁴⁷

In fact, the continuous implementation of the present response assessment criteria, the RECIST and the WHO criteria, has become controversial in the new era of medicine with biomarker-driven therapies, no matter whether for central or local assessment. For instance, when patients are treated with immunotherapies, some tumour lesions might manifest a sign of tumour 'progression' based on the RECIST/WHO criteria before manifesting a sign of tumour shrinkage, which is called pseudoprogression.¹¹⁵ Pseudoprogression was initially reported by Wolchok et al. They found that by using the immune-related response criteria (irRC), at least 10% of ipilimumab-treated patients whose response status was characterised as progression disease (PD) based on the WHO criteria could have favourable survival.¹¹⁶ The increased lesion in one case of the study was shown by histopathology as T-cell infiltration instead of tumour proliferation when PD was considered according to the WHO criteria.¹¹⁶ Similar findings have been proved by another two studies that compared the assessment of irRC with RECIST V.1.1, and immune-modified RECIST with RECIST V.1.1, respectively.^{117 118} Even though in our subgroup analysis the comparison result of central versus local assessments did not present significant difference regardless of the RECIST and WHO criteria, these criteria deserve an improvement for biomarker-driven therapies.

Our research has several limitations. First, due to using data from RCTs with both assessments, our outcome may not perfectly match all phase III trials, especially when the trials are implemented by only one type of assessment. Another situation that needs to be considered is trials evaluating two radiological assessment methods, but eventually reporting the outcomes based only on one assessment in published articles. In this situation, a statistically positive outcome may be reported in one assessment; whereas, the 'not-yet-reported' outcome of another assessment might be negative. Second, we included trials covering all solid tumours instead of focusing on one specific tumour type, in that we assumed that our research outcome could not be strongly impacted by tumours' biological characteristics when comparing specific trial processes (eg, central and local assessments)

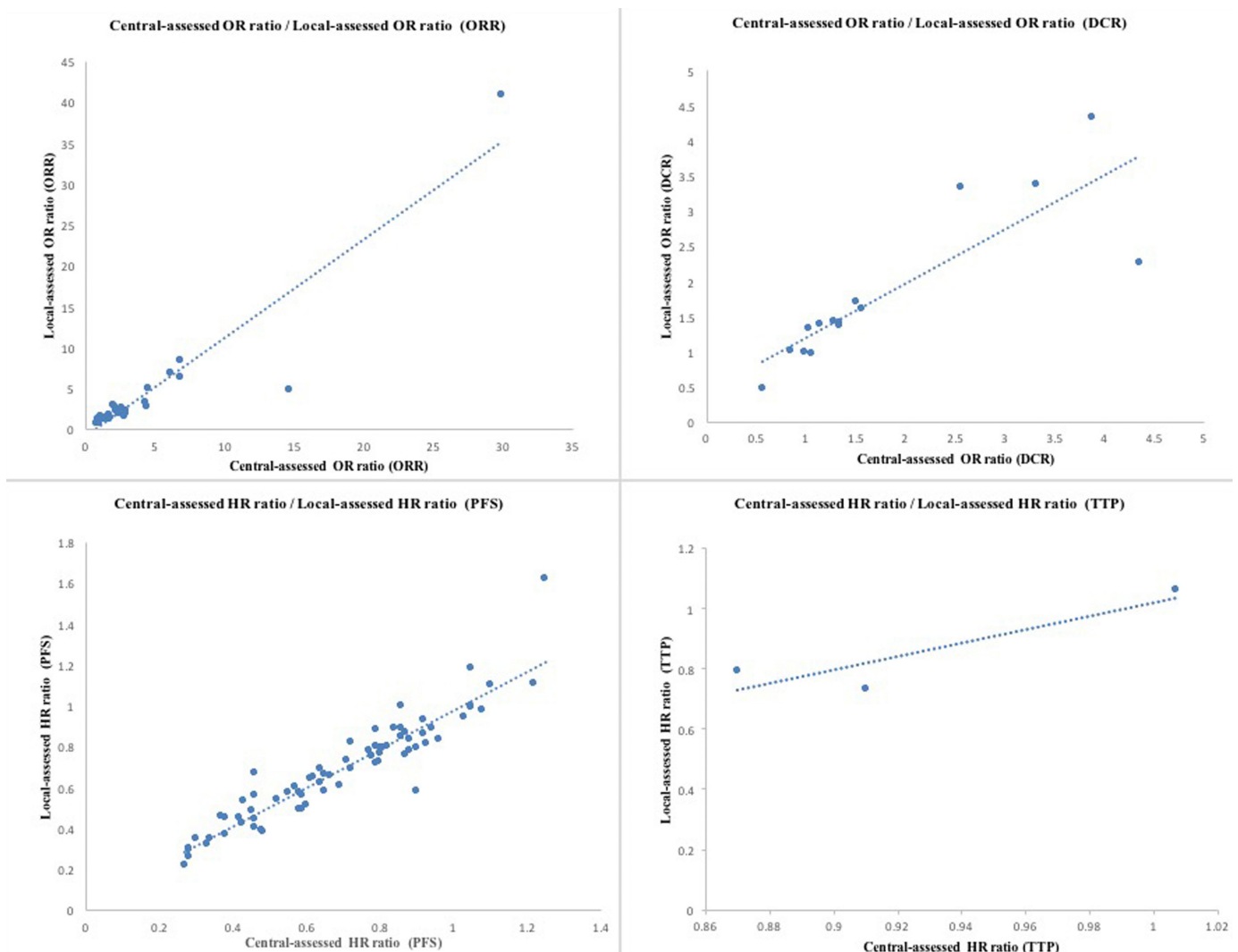


Figure 2 Scatterplot for the correlation of treatment effects between central and local assessments. DCR, disease control rate; ORR, objective response rate; PFS, progression-free survival; TTP, time to progression.

based on study-level strategy. Our subgroup analysis based on different tumour types verified our assumption.

Furthermore, individual-level data would have been the best option for our research, but we did not have access yet. However, we consider that using study-level data reported in each published article is still a good option because the aim of our research type is to investigate study-level issues. Moreover, given that the effect of informative censoring might exist on the treatment effects of PFS and TTP, we also included another important endpoint, ORR, in order to acquire a more exact understanding about whether the treatment effects of both assessments are consistent or not. In this circumstance, the effect of informative censoring could be eliminated because when assessing ORR, central reviewers and local investigators worked independently before local investigators declared progression. Lastly, even though we have done our best to minimise inconsistency during the process of data extraction, it is possible that potential errors may have accrued. Nevertheless, all reviewers have tried to ensure consistency for data interpretation.

In conclusion, we estimate that there was essentially no systematic bias between local and central assessments, as evidenced by our precisely estimated pooled ratios of OR in ORR and DCR, as well as estimated pooled ratios of HR in PFS and TTP. Despite this, we found that statistically inconsistent inferences could be made in many trials depending on whether central or local assessment was used. Considering these, we think blinded independent central review is still an irreplaceable method for controlling the risk of bias from local assessment, but its routine usage for all patients may be unnecessary in oncological randomised controlled trials.

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Contributors JRZ, WHL and JXH conceived and designed the study. JRZ conducted article researching and selection, and quality assessment. JRZ, YYZ and SYT took the lead for data extraction, which was checked by YQC, HRL, DFC, YH, XYW, KXD, SHJ, JQZ, JXX and XZC. JRZ, YYZ, SYT, LJ, QHH, LTH, JXH, ZHX and JYW analysed and interpreted the data. JRZ drafted the manuscript, which was critically revised for important intellectual content by all authors. WHL and JXH supervised the study. All authors, including JRZ, YYZ, SYT, LJ, QHH, LTH, JXH, ZHX, JYW, YQC, HRL, DFC, YH, XYW, KXD, SHJ, JQZ, JXX, XZC, WHL and JXH, have read and approved the final manuscript.

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