Definition of Oligometastatic Disease from a Radiation Oncology perspective: an ESTRO-ASTRO Consensus Document

Yolande Lievens[1]
Matthias Guckenberger[2]
Daniel Gomez[3]
Morten Hoyer[4]
Puneeth Iyengar[5]
Isabelle Kindts[6]
Alejandra Méndez Romero[7]
Daan Nevens[8]
David Palma[9]
Catherine Park[10]
Umberto Ricardi[11]
Marta Scorsetti[12]
James Yu[13]
Wendy A. Woodward[3]

[1] Department of Radiation Oncology, Ghent University Hospital; Ghent University, Ghent, Belgium
[2] Department of Radiation Oncology, University Hospital Zurich, University of Zurich, Zurich, Switzerland
[3] Department of Radiation Oncology, UT MD Anderson Cancer Center, Houston, TX, USA
[4] Danish Center for Particle Therapy, Aarhus University Hospital, Aarhus, Denmark
[5] Department of Radiation Oncology, UT Southwestern Medical Center, Dallas, TX, USA
[6] Department of Radiotherapy, Cancer Centre, General Hospital Groeninge, Kortrijk, Belgium.
[7] Department of Radiation Oncology, Erasmus MC University Medical Center, Rotterdam, The Netherlands
[8] Iridium Kankernetwerk, Radiation Oncology Department, Universiteit Antwerpen, Antwerp, Belgium
[9] London Health Sciences Centre, London, Ontario, Canada
[10] Department of Radiation Oncology, UCSF Helen Diller Comprehensive Cancer Center, San Francisco, USA
[11] Department of Oncology, University of Turin, Turin, Italy
[12] Radiotherapy and Radiosurgery dept, Humanitas Clinical and Research Hospital – IRCCS, Rozzano-Milan, Italy
[13] Yale School of Medicine, New Haven, CT.

Corresponding author
Yolande Lievens, MD, PhD
Department of Radiation Oncology
Ghent University Hospital
C. Heymanslaan 10
BE-9000 Ghent, Belgium
Tel +32 332 3075; Fax +32 332 3863
Email: yolande.lievens@uzgent.be

Highlights

- Recent prospective phase II data indicate an overall survival benefit of metastasis-directed radiotherapy (MDRT) for oligometastatic disease (OMD); however, reviewing the literature specifically for MDRT *with ablative intent* reveals heterogeneity in study design and endpoint reporting, and the observation of severe toxicities, mandate caution.
- OMD is typically based on the imaging-detected number of metastases, but definitions in the literature are inconsistent and warrant further study.
- The majority of studies included patients with synchronous or metachronous OMD, without defining the minimal disease-free interval determining prognosis. Induced OMD, occurring after systemic therapy for polymetastatic cancer, was identified as a distinct state of OMD.
- The number of lesions detected on imaging is used to determine OMD, but no formal clinical or molecular biomarkers exist to aid classification as OMD.
- The technical feasibility of safe ablative MDRT was prioritized as a minimum requirement superseding primary tumour site, number of metastases, and site of metastasis to define OMD.
- Advances in technology that facilitate the safe delivery of higher radiation doses are judged to be mandatory for optimally controlling OMD and improving outcome.

Abstract

Background:
Recognizing the rapidly increasing interest and evidence in using metastasis-directed radiotherapy (MDRT) for oligometastatic disease (OMD), ESTRO and ASTRO convened a committee to establish consensus regarding definitions of OMD and define gaps in current evidence.
Methods:
A systematic literature review focused on ablative MDRT was performed in Medline, Embase and Cochrane. Subsequent consensus opinion, using a Delphi process, highlighted the current state of evidence and the limitations in the available literature.
Results:
Available evidence regarding the use of MDRT for OMD mostly derives from retrospective, single-centre series, with significant heterogeneity in patient inclusion criteria, definition of OMD, and outcomes reported. Consensus was reached that OMD is largely independent of primary tumour, metastatic location and the presence or length of a disease-free interval, supporting both synchronous and metachronous OMD. In the absence of clinical data supporting a maximum number of metastases and organs to define OMD, and of validated molecular biomarkers, consensus supported the ability to deliver safe, clinically meaningful radiotherapy as a minimum requirement for defining OMD in the context of radiotherapy. Systemic therapy induced OMD was identified as a distinct state of OMD. High-resolution imaging to assess OMD is crucial, including brain imaging when indicated. Minimum common endpoints such as progression-free and overall survival, local control, toxicity and quality-of-life should be reported; uncommon endpoints as deferral of systemic therapy and cost were endorsed.
Conclusion:
While significant heterogeneity exists in the current OMD definitions in the literature, consensus was reached on multiple key questions. Consistent definitions and reporting are warranted and encouraged in ongoing trials and reports.

Introduction

Almost 25 years after the first description of an intermediate state between localised cancer and widespread metastatic disease, termed 'the oligometastatic state', the radical treatment of oligometastatic disease (OMD) is gaining increasing acceptance, not in the least amongst radiation oncology (RO) professionals, even if some remain hesitant to implement it routinely until stronger evidence becomes available [1-4]. Although data from randomised phase II trials of stereotactic body radiotherapy (SBRT) are emerging [5-9], there is a lack of level I evidence on the safety and efficacy of SBRT and/or more generally, MDRT ablative or otherwise, for OMD. In addition, uncertainties remain regarding the exact definition of OMD [10, 11], and reporting outcomes of patients with OMD is far from standardised, making cross-trial comparisons difficult.

Acknowledging the urgent need for standardisation within the RO community, ESTRO (European Society for Radiotherapy and Oncology) and ASTRO (American Society for Radiation Oncology) launched a collaborative project to develop consensus on patient identification and treatment of OMD. The work was performed by a group of clinical experts from Europe and the US, mandated by the respective scientific councils and boards of both societies.

This consensus paper analyses the prevailing definitions of OMD and factors that may affect these definitions. Based on a systematic literature review and using a Delphi consensus process, agreement on statements pertaining to 6 different topics related to OMD (disease characteristics, disease burden, timing of OMD, relation to other treatments, endpoints and impact of technology) is presented, along with a critical discussion based on the evidence gathered in the review. Recommendations for improving future evidence generation and reporting are formulated.

Materials and methods

Literature review

A systematic literature review, following PRISMA principles [12], was performed in Medline, Embase and the Cochrane library. The initial search performed in September 2018 included all publications until that date, reporting outcome of patients with limited metastatic burden and treated with stereotactic radiotherapy. It is acknowledged that this scope excluded studies of only non-ablative, or non-stereotactic based MDRT which may also be of inteFrest. To address limitations inherent to the rapid rate of new publications, we agreed *a priori* to repeat the systematic review for studies published between September 2018 and August 2019 to confirm robustness of the consensus findings over the timeframe of the process.

Retrospective and prospective series were included; reviews, surveys, letters and abstracts were excluded. Non-randomised reports including fewer than 50 patients treated with radiotherapy, studies solely focusing on brain metastases, not reporting clinical outcomes or solely covering non-English content were excluded (Appendix A).

Screening and initial eligibility were addressed by two authors (IK, DN), consulting others for disagreement resolution. All authors reviewed a proportion of the selected full papers for compliance with the inclusion criteria, and consistency of the data extraction was ascertained using predefined templates. Subsequently, the extracted evidence was analysed per topic: disease characteristics (AMR, DG, CP); maximum disease burden (DN, DP); timing of OMD development (MG, IK); relation of MDRT to other treatments (MH, MS, JY); relevant endpoints reported (PI, UR) and impact of technology on indication and outcome (YL, WW). The results were discussed amongst all authors and informed the Delphi process. Evidence retrieved in August 2019 was made available to support the final description.

Delphi survey

The Delphi consensus process (Appendix B) used methods previously described [13]. Consensus was defined *a priori* as ≥75% agreement on any statement. Three rounds of consensus-building were conducted using anonymous, online surveys (SurveyMonkey®). Prior to the first round, participants assembled a list of 16 key questions (KQs, Table 1) pertaining to SBRT for oligometastases and conform the 6 topics addressed in the systematic review.

Results

Literature review and Delphi process.

The systematic literature review identified 7030 potential publications in the first search and 385 in the second search, which resulted, after screening and assessment, in 75 and 23 papers respectively. After excluding one interim report identified in the first round, published with final results in the second round, the number of publications amounted to 97 (for full list, see Appendix C). As illustrated in Figure 1, there was a gap of more than 10 years between the initial publication of Hellmann and Weichselbaum and the publications fitting our search. The vast majority were retrospective reports, either single-centre (n=50) or multicentre (n=23). Six papers reported single-arm prospective cohorts; while studies reporting a phase I, II and phase II-randomised design accounted for 9, 5 and 4 publications, respectively.

There was large heterogeneity in study design: studies either reported on a variety of primary tumours or focused on specific tumour entities (e.g. prostate or lung) or metastatic sites (e.g. lymph nodes or lung metastases). The OMD definitions used across publications were equally variable (Table 2). The steps leading to the consensus statements are illustrated in Figure 2.

Consensus statements and literature discussion.

Table 1 lists the KQs and the consensus reached for each of them, below the different statements are organised in common concepts, commented by the experts and illustrated with the literature. The numbering follows that of the table.

Statements 1 and 2:

The concept of OMD is independent of primary tumour type and histology (Statement 1) and of the metastatic site(s) (Statement 2).

> Although some papers focused on a specific primary tumour type, most frequently colorectal, prostate and lung [6, 14-47], many diseases have been examined including unknown primary. Disease-specific histology has not been specified in many articles, adenocarcinoma was however frequently recorded.
>
> There was broad agreement that prognosis can differ substantially based on the primary tumour, and that some tumour types are less likely to be oligometastatic (e.g., SCLC). However, is was agreed that the concept of an intermediate state of OMD with limited metastatic capacity is unrelated to the type of primary tumour [8].
>
> Among reports focusing on site of metastases [48-74], lung, liver and lymph nodes are most widely studied. Patients with intracranial metastases are most commonly reported separately from extra-cranial OMD, but these patients should be included in future OMD studies.
> There was agreement that prognosis may vary based on the metastatic site. However, apart from patients with diffuse disease such as malignant pleural effusions, leptomeningeal or peritoneal carcinomatosis, the concept of OMD is not considered to depend of the metastatic site.

Statement 3:

There are currently no validated biomarkers that differentiate between the oligometastatic and the polymetastatic state.

The search for biomarkers indicative of OMD is an active research area, with preclinical and translational studies assessing blood-based biomarkers such as microRNA expression and circulating free DNA; tissue-based biomarkers such as mutational status and intratumoural heterogeneity; and radiomic parameters [75-78]. Ideally, integration of these categories of biomarkers into a multi-systems predictions model will lead to a more precise algorithm for defining OMD than the currently most often used number of metastatic lesions, and thus aid in assigning the appropriate treatment.

Statement 4:

Diagnostic imaging should be performed using whichever modalities that are most adequate to image sites of common metastases and to detect small lesions for that histology.

Multi-modality diagnostic imaging was used for the evaluation of metastatic disease in most studies reviewed [43]. Although several studies did not specify modalities used in OMD workup [28, 79], in areas of focused disease-site evaluations, highly specific imaging was utilized (e.g., contrast-enhanced bi-phasic liver CT for liver metastases [26], PSMA-PET for prostate OMD [33].

While there was no consensus to recommend specific imaging modalities as a requirement for OMD workup, there was consensus to recommend PET/CT, chest/abdominal and pelvis CT scans, and MR brain (when indicated) for diagnostic evaluation. Further, reflective of the future development of imaging technologies in certain areas, there was consensus to recommend any validated imaging modalities that adequately image sites of common metastasis and to detect small lesions.

Statements 5, 6, and 13:

The feasibility of safely delivering ablative MDRT determines the maximum number of lesions and sites *that can be treated with radiotherapy** in OMD. The ability to safely treat all oligometastases with radiotherapy does not mean that one should treat every patient irrespective of other prognostic factors (Statement 5). Regardless of the number of metastases, the risks and benefits of MDRT should be balanced carefully in all oligometastatic patients (Statement 6). The risk of toxicity impacts treatment indications for OMD (Statement 13).

**Italicized text added after consensus was formed to provide needed clarification highlighted during the review process.*

Reviewing the literature, 'up to 5' and 'up to 3' oligometastatic lesions are the most commonly-used quantitative definitions. Similar limits were sometimes placed on the maximum number of metastases per organ (Table 2). However, studies differ on whether the primary tumour is counted (for patients with synchronous oligometastases), on imaging modalities and their sensitivity used for patient staging, and whether regional lymph node targets are counted as individual targets or grouped together. Several papers have no maximum number of lesions defined, nor report median or range.

At present, there is no biological evidence supporting the maximal number of metastases, or the maximal lesion size, that can be treated to provide clinical benefit. In treatment planning,

the upper limit of technically safe ablative MDRT is not well-studied. No studies that met the review criteria attempted to determine the maximum lesion number or size. A maximum cut-off size of 5cm is sometimes used, but larger lesions may be treatable depending on location and with careful attention to dose constraints, recognizing size is prognostic for control in multiple studies [22, 23, 37, 79, 80].

In the absence of sensitive and specific biomarkers, with number of metastatic lesions and organs commonly being used as surrogates for patient selection, the consensus obtained regarding maximum number of lesions that can be considered as OMD was that the maximum number must be limited by the ability to deliver safe ablative MDRT, which can vary on a case-by-case basis. This agrees with surgical strategies where technical resectability, not a fixed number of metastases, decides for or against a metastasis-directed treatment strategy. It also considers patients who may have few lesions, but where the safety of delivering an adequate dose is questionable. Recognizing future technologies may increase the feasibility of targeting more advanced disease, there was also consensus that the technical ability to treat numerous lesions safely should not lead to expanded selection criteria off-protocol or not supported by clinical data.

Importantly, treatment-related death [8, 65, 66, 73, 81] and other serious toxicities [55, 56, 61, 68] are uncommon, but they have been reported. The utilization and benefits of MDRT for OMD must be determined by the therapeutic ratio of efficacy to toxicity. Normal tissue toxicity is dependent on the anatomic location of disease receiving therapy and should be measured with standard toxicity metrics.

Statements 7 and 9:

OMD is differentiated into synchronous versus metachronous states, defined by the interval between primary cancer diagnosis and development of OMD (Statement 7). A disease-free interval (DFI) is not mandatory to define OMD (Statement 9).

The main categorization in the literature reviewed was synchronous versus metachronous (often referred to as oligorecurrent) OMD, typically differentiated by a time interval of 3-6 months between primary cancer diagnosis and development of OMD (Table 2). When reported, the primary tumour had frequently been treated with curative intent in metachronous OMD. A locoregionally controlled primary tumour is not a precondition but should be considered a prognostic parameter which is critical to report specifically. Some studies reported a better prognosis for metachronous OMD [24, 82], but this was not consistently observed [21, 70].

Though both synchronous and metachronous metastases are considered OMD, the prognosis, options for treatment and risk of occult disseminated metastases of these patients can differ, with the length of the DFI appears to have a prognostic impact [42, 65, 83]. While concerns were raised about prognosis of metastases developing shortly after primary cancer treatment, uncertainty remains regarding the importance of the DFI, as data are lacking to support a consensus for minimum DFI in the definition of metachronous OMD.

Statements 8, 11 and 12:

Patients with prior polymetastatic disease can become OM based on response to systemic therapy (Statement 12). Different states of systemic therapy induced OMD are reported in the literature with inconsistent nomenclature and definitions (Statement 8). There was no consensus on the criteria for a maximum number of metastases or organs for systemic therapy induced OMD (Statement 11).

There is growing but still limited evidence on the development of OMD after systemic therapy for polymetastatic disease. While it was agreed that originally polymetastatic disease that becomes OMD should be defined as 'induced OMD', concerns were raised on the difficulty in histopathologic confirmation of polymetastatic disease, and the potential importance of local tumour control. It was also cautioned that the treatment goal in induced OMD may not be improved survival as polymetastatic disease is generally considered 'incurable' for most malignancies but may be improved progression-free survival (PFS) or local control (LC).

In the context of systemic therapy induced OMD, additional conceptual states of OMD are described in the literature e.g., oligoprogressive or oligopersistent disease. However, definitions of those terms varied in original research and in review articles (Table 2) [84-87]. Oligoprogression on systemic therapy is clearly a different clinical entity than OMD, with evidence for worse prognosis compared to de novo or isolated metastatic disease [35, 37, 44, 79, 88].

Statement 10:

A treatment-free interval (TFI) is not mandatory to define OMD.

Similar as for DFI, the heterogeneous reporting of TFI and disease at initial presentation is observed in the literature.

There was consensus that the relation of OMD states to the treatment status (during or after systemic therapy or after a minimum DFI) is of paramount importance to defining the relevant clinical scenario, but questions remain about these multiple clinical situations where OMD can arise as above, hence the multiple interpretations of 'TFI'. In some OMD states, TFI would have prognostic value (in the case of initially localized disease), in others it would ideally be minimized in a treatment course (in the case of initially polymetastatic disease). Complete reporting of primary presentation and subsequent systemic therapy is critical for future study.

Statement 14:

Overall survival (OS), disease-free survival (DFS) or PFS, local, toxicity, quality-of-life (QoL), patient-reported outcome measures, cost, delay or deferral of systemic therapy and ability to stay on the same line of systemic therapy are all considered important endpoints.

In the literature, efficacy of treatment for OMD is measured by various parameters, OS, PFS, LC and toxicity being most frequent. QoL and patient-reported outcome measures are infrequently identified based on our analysis of studies represented in this paper's literature review.

In the Delphi consensus, OS had the strongest support for being critical to showing benefit of MDRT for OMD, followed - in decreasing order - by PFS, LC, toxicity, QoL, patient-reported outcome measures, cost, delay or deferral of systemic therapy, and finally ability to stay on same systemic therapy without change.

While international criteria have been proposed for endpoints evaluating the benefit of oncology drugs (and support their reimbursement), it is acknowledged that other endpoints may also be important in the context of loco-regional oncology interventions [89-91].

Statements 15 and 16:

Although technology *per se* does not impact the indications, adequate technology and/or techniques (e.g., SBRT or hypofractionated image-guided radiotherapy) are a minimum requirement to treat OMD when pursuing ablative intent (Statement 15). Although likely there will be variation as the data emerge, the goal is control of the targeted metastasis and the current data support >100Gy biologic equivalent dose (BED; Statement 16) when it can be safely delivered.

The primary goal of delivering ablative MDRT is to maximize tumour control while minimizing short and long-term effects of radiation. Therefore, every effort should be made to ensure precise delivery of radiotherapy using all available technological resources. More advanced technologies that facilitate smaller set-up margins, without compromising tumour coverage while limiting dose to normal tissues, have facilitated the increased interest in defining and treating OMD. Lack of motion management use [48, 59], planning target volume size [19, 59, 80, 92] and coverage [69, 72] have been associated with lower tumour control. Overall however, detailed reporting of planning constraints and protocol deviations is minimal in the literature reviewed, highlighting an area in need of improvement. While there are not sufficient literature data to address dose and BED by primary and in all relevant contexts, the convergence of existing data highlighting improved LC of the targeted metastasis with a minimum of 100Gy BED_{10} makes this a goal when feasible until further evidence emerges [19, 31, 40, 48, 59, 63, 69, 74, 93]. It is noted however that in sites where normal tissue constraints make this infeasible near the bowel, great vessels or spinal cord, lower BEDs have been associated with control [94, 95] and future studies may identify clinical scenarios where lower doses are adequate. Additionally, studies addressing systemic therapy induced OMD used lower radiation doses compared to studies addressing synchronous or metachronous OMD.

Discussion

Increasing enthusiasm for and technology to support safe radiation treatment of OMD has already led to a sharp increase in data in this field, and more trials are rapidly accruing to define the role of ablative or at a minimum non-palliative MDRT in the context of the actual standards of care, of new systemic treatment strategies and compared to other local interventions. Meanwhile, this systematic literature review demonstrated substantial heterogeneity amongst the ablative MDRT publications in terms of patients included, endpoints reported, and definitions used (Table 2). These findings guided the development of key unanswered questions, leading to consensus using the Delphi process. Key points, summarized in Table 1, emphasize there are not yet adequate biomarkers, including number of metastases, to conclude that primary tumour or metastatic site, response to therapy, or DFI limits preclude a potential oligometastatic state. It is clear many of these factors impact prognosis, however, explicitly describing the patient population studied and outcomes using consistent language is paramount to future progress.

In the absence of relevant biomarkers, the OMD state is currently defined based on imaging. To homogenise diagnostic requirements, the EORTC (European Organisation for Research and Treatment

of Cancer) Imaging Group has proposed minimal criteria for diagnostic imaging to define OMD [96]. To address the heterogeneity and uncertainties of OMD in its clinical implementation, ESTRO and EORTC have also jointly initiated OligoCare under the E2-RADIatE platform (EORTC-ESTRO RADiation InfrAstrucTure for Europe, NCT03818503). This international prospective registry trial aims to identify patient, tumour, staging, and treatment characteristics that impact OS of patients treated with radical radiotherapy for OMD. The inclusion criteria are broad to reflect the diversity of daily clinical practice and to allow the identification of relevant prognostic and predictive factors. In this frame, an OMD characterization system has been developed to classify distinct oligometastatic states and assign a consensus nomenclature (personal communication). The authors herein endorse the OligoCare consensus and encourage using this approach to unify definitions internationally.

The fast pace of clinical data emerging in this field limits the output of systematic literature review. Although level 1 evidence is still limited, multiple randomized trials are expected in the next few years. A recent review reports 64 ongoing trials studying ablation of OMD activated and accruing through February 2019 [97]. Over half were phase II (*n* = 35), however, 17 randomized controlled trials were noted. Along with real-world data, these trials are expected to shed light on the benefit of ablative radiotherapy in the context of OMD.

In conclusion, considerably more data are needed to define the optimal patient selection for ablative MDRT for OMD. Synchronous and metachronous OMD are currently best defined as distinct disease states. Others such as oligorecurrence, progression and -persistence are plausible scenarios where clinically evident disease may represent the true disease state as opposed to impending wide spread disease. Based on ongoing trials it is clear that further complexity will be added regarding the use of concurrent systemic therapy or immunotherapy [97]. It is therefore critical that authors and editors are explicit about inclusion criteria and definitions, endpoints and toxicity.

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