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RESEARCH ARTICLE

Radiofrequency for chronic lumbosacral and cervical pain: Results of a consensus study using the RAND/UCLA appropriateness method

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Abstract

Background: Despite the routine use of radiofrequency (RF) for the treatment of chronic pain in the lumbosacral and cervical region, there remains uncertainty on the most appropriate patient selection criteria. This study aimed to develop appropriateness criteria for RF in relation to relevant patient characteristics, considering RF ablation (RFA) for the treatment of chronic axial pain and pulsed RF (PRF) for the treatment of chronic radicular pain.

Methods: The RAND/UCLA Appropriateness Method (RUAM) was used to explore the opinions of a multidisciplinary European panel on the appropriateness of RFA and PRF for a variety of clinical scenarios. Depending on the type of pain (axial or radicular), the expert panel rated the appropriateness of RFA and PRF for a total of 219 clinical scenarios.

Results: For axial pain in the lumbosacral or cervical region, appropriateness of RFA was determined by the dominant pain trigger and location of tenderness on palpation with higher appropriateness scores if these variables were suggestive of the diagnosis of facet or sacroiliac joint pain. Although the opinions on the appropriateness of PRF for lumbosacral and cervical radicular pain were fairly dispersed, there was agreement that PRF is an appropriate option for well-selected patients with radicular pain due to herniated disc or foraminal stenosis, particularly in the absence of motor deficits. The panel outcomes were embedded in an educational e-health tool that also covers the psychosocial aspects of chronic pain, providing integrated recommendations on the appropriate use of (P)RF interventions for the treatment of chronic axial and radicular pain in the lumbosacral and cervical region.

Conclusions: A multidisciplinary European expert panel established patient-specific recommendations that may support the (pre)selection of patients with chronic axial and radicular pain in the lumbosacral and cervical region for either RFA or PRF (accessible via https://rftool.org). Future studies should validate these

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recommendations by determining their predictive value for the outcomes of (P)RF interventions.

KEYWORDS
cervical pain, chronic pain, e-health tool, facet pain, low back pain, lumbosacral pain, patient selection, PRF, pulsed radiofrequency, radicular pain, radiofrequency ablation, radiofrequency, RFA, sacroiliac pain

INTRODUCTION

A substantial part of the general population experiences one or more periods of chronic low back or neck pain throughout life.[1–3] Chronic axial lumbosacral and cervical pain can be attributed to different anatomic structures, including but not limited to the facet joints, sacroiliac joints, muscles, and intervertebral discs. All these aspects should be considered in the diagnostic evaluation following the exclusion of red flag causes, such as inflammation, trauma, and malignancies.[1,4–8] Generally, first-line management of axial pain consists of conservative treatment, including analgesic medication, physical therapy, and patient education.[6,9] If axial pain persists despite appropriate conservative management, further evaluation, including physical examination and imaging, can help the differential diagnosis. However, because there is ongoing debate regarding the diagnostic utility of clinical features and radiological findings, a medial or lateral branch block or sacroiliac joint injection should be performed when suspecting facetogenic or sacroiliac joint pain.[10–12] If the response is positive (≥50% pain relief after local anesthetic without corticosteroids), evidence-based and consensus practice guidelines recommend the use of thermal radiofrequency ablation (RFA) of the medial branches that innervate the facet joints or the lateral branches that innervate the sacroiliac joints.[1,13–16]

In the differential diagnosis, it is furthermore important to differentiate referred (pseudoradicular) from radicular pain, with the latter type of pain being typically sharp and lancinating in nature and possibly accompanied by neurological signs (radiculopathy).[17] Although persistent radicular pain is less common than chronic axial pain, it is also an important reason for patient referral to pain clinics, neurologists, neurosurgeons, and orthopedic spine surgeons.[18,19] For refractory radicular pain, different non-surgical pain interventions are available, including epidural and transforaminal steroid injections.[20–22] As an alternative or adjuvant to steroid injections, pulsed RF (PRF) treatment adjacent to the dorsal root ganglion (DRG) can be considered, albeit that controversy exists around its use despite the moderate-level evidence on beneficial outcomes that have been reported in smaller observational and randomized controlled trials.[23–27]

Furthermore, there remains considerable uncertainty and disagreement on the appropriate patient selection criteria for both RFA and PRF for the treatment of chronic axial and radicular pain in the lumbosacral and cervical region. Several studies have tried to identify factors predictive of either success or failure of (P)RF interventions, but the results are inconclusive and often conflicting.[10,11,28–31] In this consensus study, a European expert panel established a set of patient-specific recommendations based on available evidence and clinical expertise that may aid physicians with the referral and selection of patients with chronic lumbosacral and cervical pain for (P)RF. The panel recommendations, considering both clinical and psychosocial factors, were embedded in an educational e-health tool that was developed to facilitate their adoption. In addition to supporting patient selection, the e-health tool offers guidance on the appropriate (technical) application of RFA for axial pain and PRF for radicular pain.

METHODS

Study design

The RAND/UCLA Appropriateness Method (RUAM) was used to develop referral and selection criteria for (P)RF in patients with chronic lumbosacral and cervical pain, considering RFA for axial pain and PRF for radicular pain. By applying a modified Delphi approach that combines the best available scientific evidence with clinical judgment, the RUAM systematically canvasses the opinions of experts on the appropriateness of medical, surgical, and diagnostic procedures.[32,33]

Study preparation

The study was initiated and prepared by three anesthesiologists (JAA, SE, and FH) and two methodologists (HJS and NH) who had been involved in previous applications of the RUAM methodology in the field of chronic pain. These five people formed the Steering Committee.

Panel composition

Following the RUAM principles, we composed a panel that was sufficiently large to show the dispersion of opinions and small enough to allow all panelists to participate in the discussions.[32] As patient selection for

(P)RF is mainly done by the performers themselves, we abstained from a broad multidisciplinary approach, and involved two specialties that are most frequently involved in performing RF (anesthesiology and neurosurgery). The Steering Committee nominated seven additional candidates based on their scientific and clinical experience with (P)RF for treating chronic pain, bringing the total group of experts participating in the consensus voting to 10 anesthesiologists and three neurosurgeons. The panelists represented eight European countries (Belgium, France, Germany, Italy, Spain, Switzerland, The Netherlands, and the UK) to ensure a reasonable geographic spread.

Literature review

A literature search was conducted on the efficacy and safety of (P)RF for the treatment of chronic axial and radicular pain in the lumbosacral and cervical region using the PubMed database for the period 2012–2022. This search took a hierarchical approach starting with the highest quality evidence, including systematic literate reviews, meta-analyses, and randomized controlled trials. Another PubMed search focused on identifying evidence about predictive factors of success and failure for the selected (P)RF indications. Furthermore, an overview of society and country-specific guidelines on (P)RF interventions was compiled. The results of the literature searches were first used to support shaping the starting points of the study. In addition, an overview was available for the panelists while doing the ratings to ensure that they had access to the same body of evidence.

Panel process

The panel process is depicted in Figures 1 and 2. The conceptual starting points of the study were established during a Steering Committee meeting (September 2021, Paris and France), discussing the indications to be included, absolute inclusion and exclusion criteria, and factors predictive of treatment outcomes. Two indication areas for (P)RF were selected: chronic low back and/or leg pain and chronic neck and/or arm pain. For these two indication areas, clinical variables deemed relevant in the (pre)selection of patients with chronic pain for (P)RF were identified, resulting in a total of 1296 clinical scenarios. The 13 panelists then individually and anonymously rated the appropriateness of (P)RF for all scenarios on a 9-point scale (reference values: 1=inappropriate, 5=uncertain/equivocal, and 9=appropriate). They were instructed to consider only the clinical perspective and to disregard other potential constraints such as costs, reimbursement conditions, and differences between devices. During the first rating round, the experts were asked to rate the appropriateness of RF regardless of the type. The decision for the most appropriate RF technique (RFA or PRF) was assumed to be the competence of the RF performer.

The results of the first rating round were analyzed by the non-voting methodologists and discussed during the first expert panel meeting (March 2022, Amsterdam and The Netherlands). It was concluded that the type of pain, axial versus radicular, should be specified to differentiate between indications for RFA and PRF. This led to the inclusion of additional clinical variables and the removal of others. Since the diagnostic/prognostic block should always be positive (ie, result in ≥50% pain relief after local anesthetic without corticosteroids) before performing RFA, it was decided not to include this as a clinical variable in subsequent rating rounds, as it would overrule all other predictive factors. Instead, it was concluded that the appropriateness criteria for patient selection should be applied before knowing the result of a diagnostic/prognostic block. In addition to the clinical variables, the absolute patient selection criteria were further refined based on the panel discussion (Table 1).

In the RAND/UCLA approach, a treatment is considered appropriate if the expected benefits outweigh the expected risks by a sufficient margin that the procedure is worth doing.[32] The panel defined the minimum clinically significant change to consider (P)RF positive as a 30% improvement from baseline for at least 3 months. According to a consensus document by Ostelo et al, this corresponds to ≥15 mm on the visual analog scale (VAS) and/or ≥2 points on the numeric rating scale (NRS).[34] Using this definition, the 13-member panel anonymously rated the appropriateness of RFA and PRF for a set of 234 and 66 clinical scenarios, respectively, during the second rating round. In the same vein as the first rating round, only clinical factors were considered, first-time use of (P)RF was assumed and the new definition of appropriateness was adopted. The second rating round revealed marked differences in the ratings between and within specialties.

A survey was conducted to understand whether these differences were due to misinterpretation of clinical variables and/or practice variations. The expert panel was asked whether they considered RFA to be an option for facet joint, sacroiliac joint, and discogenic pain and PRF for lumbosacral and cervical radicular pain. In addition, four statements on the diagnosis underlying a certain pain trigger for axial lumbosacral and cervical pain were rated on a 5-point Likert scale to assess the level of agreement among the panelists. Based on the survey outcomes and discussions during the second virtual panel meeting (August 2022), ambiguous clinical variables were revisited, and ratings were repeated.

The third and final rating round comprised 219 clinical scenarios across two indication areas for which the appropriateness of RFA or PRF was rated depending on the type of pain (axial versus radicular) (Table 2). The panel further selected a set of four psychosocial factors that may be important when evaluating the patient's eligibility for (P)RF. These were derived from a previously

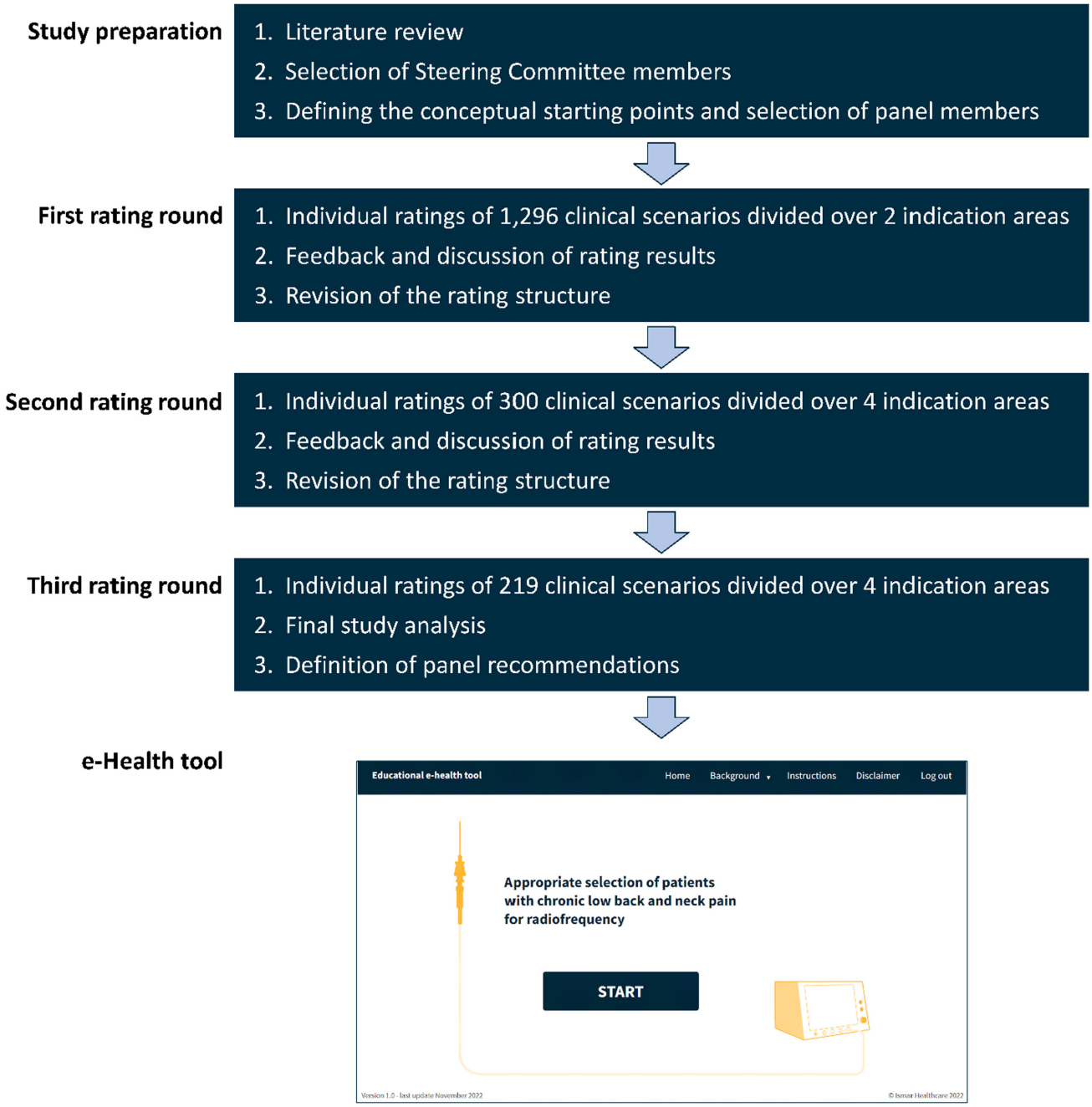

FIGURE 1 Flow chart of the panel study.

conducted RUAM study on patient selection for spinal cord stimulation (SCS)[35] and included the following: dysfunctional coping, unrealistic expectations, psychological distress/mental health problems, and unwilling to reduce high-dose opioids.

Appropriateness calculations and statistical analysis

Similar to other RUAM studies, appropriateness of (P)RF was calculated by the median panel score and the extent of agreement among the panelists. (P)RF was considered appropriate if the median panel score was between 7 and 9, uncertain if the median was between 4 and 6, and inappropriate if the median was between 1 and 3. For scenarios with disagreement between the panelists (at least one-third of the panel scored in each of the sections 1–3 and 7–9), appropriateness of (P)RF was considered uncertain/equivocal regardless of the median panel score.[32] Frequency tables and cross-tabulations were used to describe and analyze the survey results and appropriateness outcomes. For the survey results, a threshold of 75% agreement among the panelists was used to define consensus.

TABLE 1 Inclusion and absolute exclusion criteria for (P)RF selected by the expert panel.

Inclusion criteria	Exclusion criteria
• Age ≥ 18 years • Chronic pain persisting for ≥3 months • Pain severity at least moderate (VAS ≥4) • Insufficient response to conservative management	• Unwilling to undergo the (P)RF procedure • Infection at the presumed treatment site or systemic infection • Major motor weakness and severely progressive neurologic dysfunction • Following specific pain syndromes: widespread pain, thoracic pain, spondylolysis, spondylodiscitis, coccygodynia, pain after fracture, cancer pain, and cauda equina syndrome

TABLE 2 Overview of variables and corresponding categories used for the construction of scenarios in the third rating round.

Chapter	Clinical variables	Categories
Chronic axial lumbosacral pain	1. Dominant pain trigger	Pain on lateral flexion; pain on coughing, sneezing, and straining; sacroiliac joint provocation tests
	2. Dominant location of pain on lateral flexion	Ipsilateral; contralateral; non-specific; not applicable
	3. Dominant location of pain on coughing, sneezing, and straining	Midline lumbar spine; lateral lower limb; non-specific; not applicable
	4. Location of tenderness on palpation	Midline; paravertebral; non-specific
Chronic axial cervical pain	1. Whiplash-associated disorder	Grade I; Grade II; no complaints/history
	2. Dominant pain trigger	Pain on lateral flexion; pain on coughing, sneezing, and straining
	3. Dominant location of pain on lateral flexion	Ipsilateral; contralateral; non-specific; not applicable
	4. Dominant location of pain on coughing, sneezing, and straining	Midline cervical spine; lateral upper limb; non-specific; not applicable
	5. Location of tenderness on palpation	Midline; paravertebral; non-specific
Chronic lumbosacral radicular pain	1. Cause of pain	Disc herniation; foraminal stenosis; spinal stenosis; PSPS type 2 (FBSS); other/unknown
	2. Neurological symptoms	Absent; sensory disturbances; motor deficits; mixed (sensory and motor)
	3. Lasègue test	Negative; positive; not performed
Chronic cervical radicular pain	1. Whiplash-associated disorder	Grade III; no complaints/history
	2. Cause of pain	Disc herniation; foraminal stenosis; spinal stenosis; other/unknown
	3. Neurological symptoms	Absent; sensory disturbances; motor deficits; mixed (sensory and motor)
	4. Spurling test	Negative; positive; not performed

Abbreviations: FBSS, failed back surgery syndrome; PSPS, persistent spinal pain syndrome.

Educational e-health tool

The appropriateness statements and panel considerations were embedded in an educational e-health tool that aims to support healthcare professionals with the referral and selection of patients with chronic axial and radicular pain in the lumbosacral and cervical region for (P)RF interventions. The tool has a multilayer format, consisting of the following elements: (1) inclusion and exclusion criteria, (2) indication area, (3) type of pain, (4) clinical profile, (5) psychosocial profile, (6) composite recommendation, and (7) technical specifications. Details on the construction of the e-health tool are provided in the supporting materials (Figure S1).

RESULTS

Chronic axial lumbosacral and cervical pain: Appropriateness of RF ablation

Overall, RFA was considered to be appropriate for 9% of the axial lumbosacral and cervical pain scenarios, while 14% and 33% of the clinical scenarios on chronic axial lumbosacral and cervical pain, respectively, were deemed inappropriate (Figure 2). Disagreement within the 13-member expert panel was limited and all panelists considered RFA considered to be an option for facet and sacroiliac joint pain (Figures S2 and S3).

Appropriateness patterns of RFA for the treatment of patients with chronic axial lumbosacral pain are shown

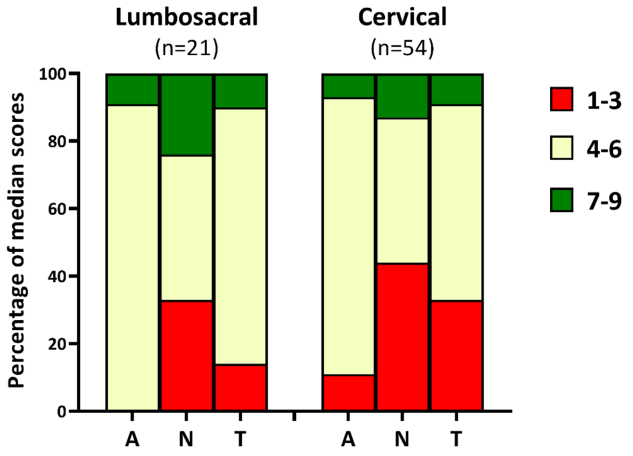

FIGURE 2 RFA appropriateness results by indication area and panelists' specialty. Percentage of median scores in each of the sections 1–3 (inappropriate), 4–6 (uncertain/equivocal), and 7–9 (appropriate). N represents the number of scenarios per indication area. A, Anesthesiologists; N, Neurosurgeons; T,Total.

in Figure 3A. In the case, the dominant pain trigger was pain on lateral flexion, appropriateness of RFA was highest if the pain was experienced at the ipsilateral side and characterized by paravertebral tenderness on palpation. RFA was considered inappropriate for scenarios where pain was predominantly experienced in the midline lumbar spine on coughing, sneezing, and straining. For pain reproduced by sacroiliac joint provocation tests, RFA was considered appropriate only if tenderness on palpation was located paravertebrally. All other outcomes were uncertain/equivocal.

Comparable patterns of appropriateness were seen for RFA to treat chronic axial cervical pain (Figure 3B). Appropriateness was limited to scenarios where pain was exacerbated on lateral flexion and the location of tenderness on palpation was paravertebral. Appropriateness figures were similar in case of a history of whiplash-associated disorder (WAD) (Grade I or II). Inappropriateness was exclusively associated with pain on coughing, sneezing, and straining, especially if the distribution of pain was diffuse or radiating to the upper limb.

Chronic lumbosacral and cervical radicular pain: Appropriateness of pulsed RF

The ratings showed that there was disagreement on the appropriateness of PRF for some of the included patient profiles, with diverse attitudes toward PRF within the expert panel (Figure 4; Figures S2 and S3). Out of the 13 experts, 10 (eight anesthesiologists and two neurosurgeons) considered PRF to be a treatment option for lumbosacral radicular pain and 9 (all anesthesiologists) for cervical radicular pain.

For PRF treatment of the lumbar DRG, appropriateness was highest if the pain was caused by disc herniation or foraminal stenosis in the absence of motor deficits (Figure 5A). Due to differences between specialties and practice variations, there was a high level of disagreement between the panelists resulting in a large number of uncertain outcomes. Anesthesiologists considered PRF more often appropriate than neurosurgeons who were against its use in the presence of motor deficits. As expected, experts classified as being non-believers did not consider PRF to be appropriate, though some scenarios were deemed uncertain/equivocal, especially those without motor deficits (Figures S4 and S5).

Overall, appropriateness outcomes were similar between chronic lumbosacral and cervical radicular pain (Figure 5B). In the case radicular symptoms were associated with Grade III WAD, PRF was considered appropriate if the pain was caused by disc herniation or foraminal stenosis with only sensory disturbances and confirmation of cervical radiculopathy by a positive Spurling test. However, neurosurgeons and experts not considering PRF to be a treatment option for cervical radicular pain were, in general, against its use in patients with Grade III WAD (Figures S6 and S7).

Educational e-health tool

The appropriateness results were embedded in an educational e-health tool (https://rftool.org) that aims at supporting healthcare professionals to consider the eligibility of patients with chronic axial and radicular pain in the lumbosacral and cervical region for (P)RF in a stepwise approach (Figure 6; Figure S1). After confirming that the inclusion and exclusion criteria are met (Table 1), the referrer or performer has to decide whether the patient has axial or radicular pain based on a set of predefined criteria. Depending on the clinical factors, the tool provides a recommendation on the appropriateness of RFA for axial lumbosacral and cervical pain, and of PRF for lumbosacral and cervical radicular pain. If the clinical outcome is appropriate or uncertain/equivocal, the presence of any compromising psychosocial factors has to be considered as the next step. Based on a patient's clinical and psychosocial factors, a composite recommendation on (P)RF is provided to either the referrer (referral is not recommended, recommended, or strongly recommended) or RF performer (RF is rarely appropriate, may be appropriate, or usually appropriate). When (P)RF is considered an option, technical specifications on the application of the (P)RF intervention for the treatment of facet joint, sacroiliac joint, and radicular pain are accessible to the (P)RF performer. For axial pain, the e-health tool is intended to be used prior to performing a diagnostic medial branch block (in the case of facet pain) or lateral branch block (in the case of SI joint pain). If the composite recommendation on RFA is either "usually appropriate" or "may be appropriate," a diagnostic block should be performed first where the result has to be positive (≥50% perceived pain

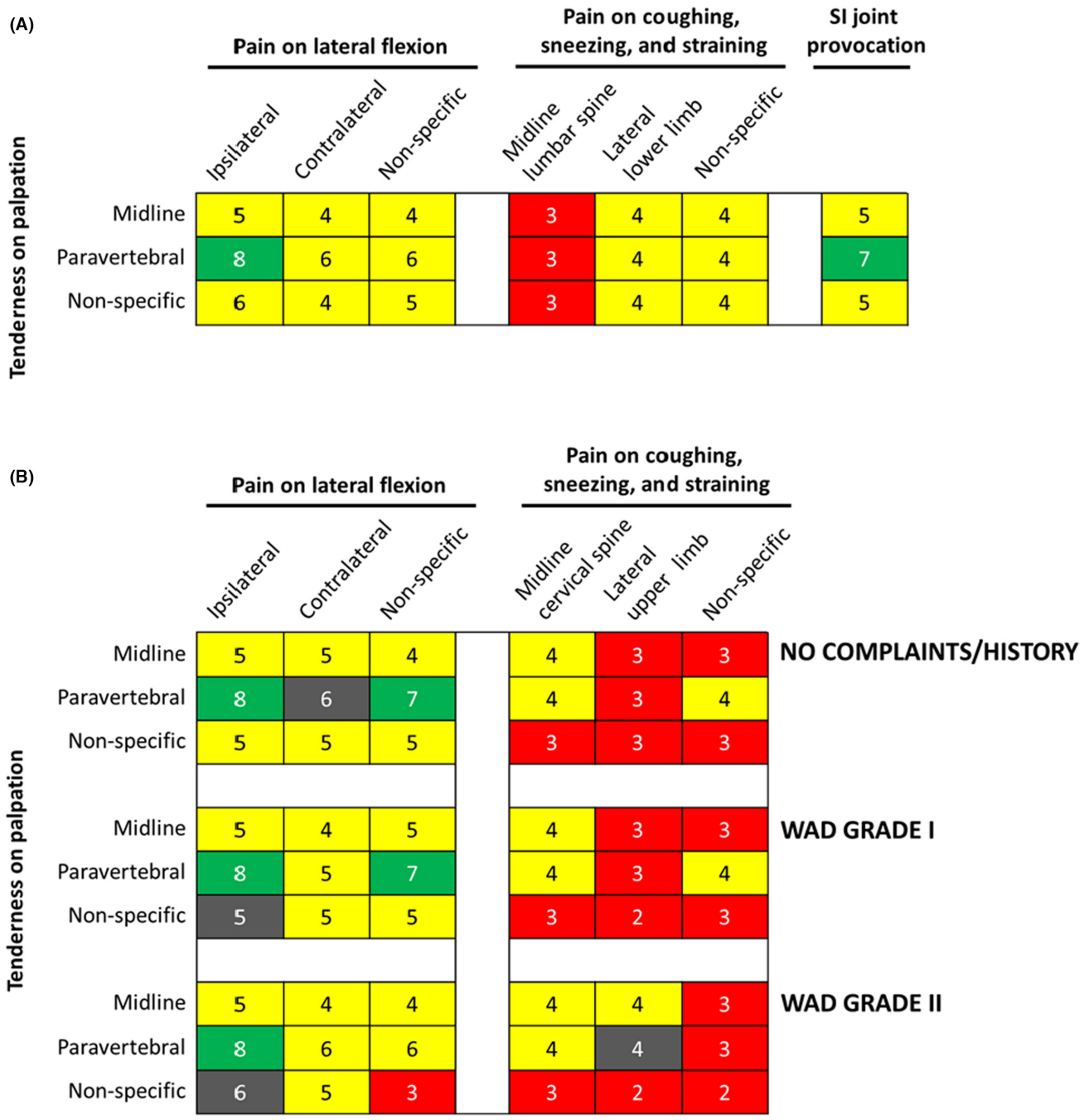

FIGURE 3 Appropriateness patterns of radiofrequency ablation (RFA) for the treatment of chronic axial lumbosacral (A) and chronic axial cervical pain (B). Numbers represent the median panel scores. Colors denote the appropriateness outcome (red = inappropriate; yellow = uncertain/equivocal; green = appropriate; gray = disagreement). WAD, whiplash-associated disorder.

relief) before further consideration of RFA. For PRF, a diagnostic block was not considered a prerequisite.

DISCUSSION

Chronic axial lumbosacral and cervical pain

RFA has been used for many years to alleviate chronic axial lumbosacral and cervical pain refractory to conservative treatment options. Based on a summary of the latest evidence, different pain societies consider RFA to be a minimally invasive and safe option for the treatment of chronic axial lumbosacral pain originating from the facet or sacroiliac joints.[1,16] However, there remains disagreement on its short- and long-term benefits since mixed results have been reported by randomized controlled trials.[36–47] Although one of these trials (MINT) did not show added benefits of RFA over a physiotherapy program, the authors themselves suggested that better patient selection may lead to better results.[44] However, until now, the available literature is rather unclear about appropriate

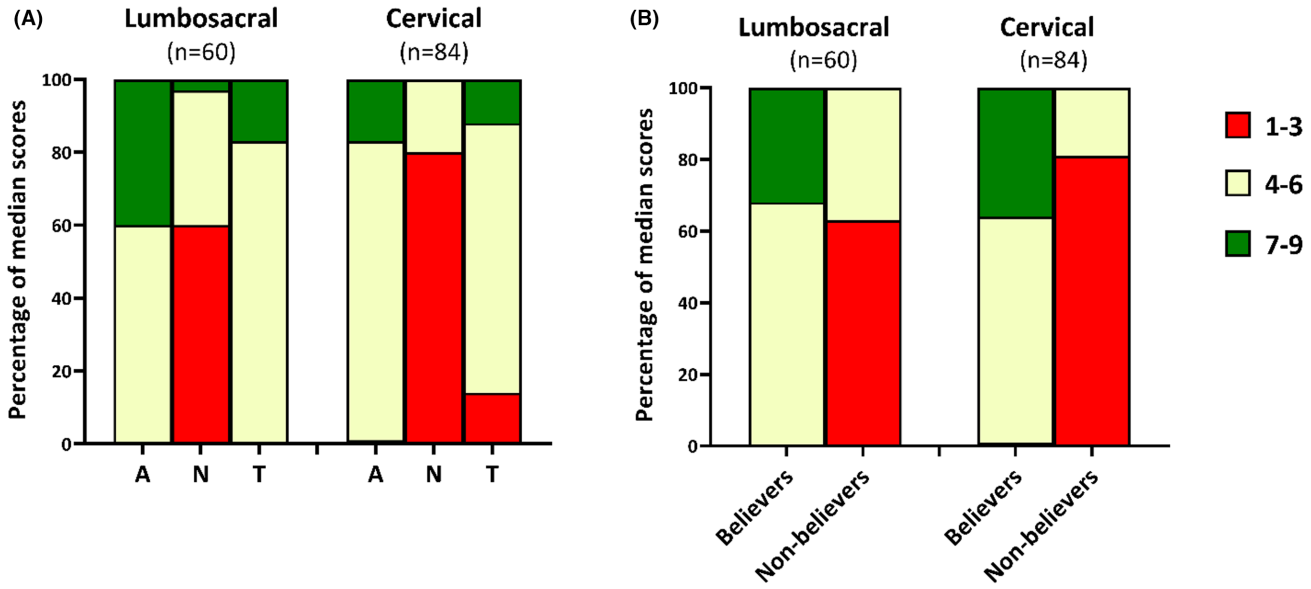

FIGURE 4 Appropriateness results by indication area and panelists' specialty (A) and by attitudes toward pain and pulsed radiofrequency (PRF) (B). Believers consider PRF an option for the displayed indications, while non-believers have the opposite opinion. Percentage of median scores in each of the sections 1–3 (inappropriate), 4–6 (uncertain/equivocal), and 7–9 (appropriate). N represents the number of scenarios per indication area. A, Anesthesiologists; N, Neurosurgeons; T,Total.

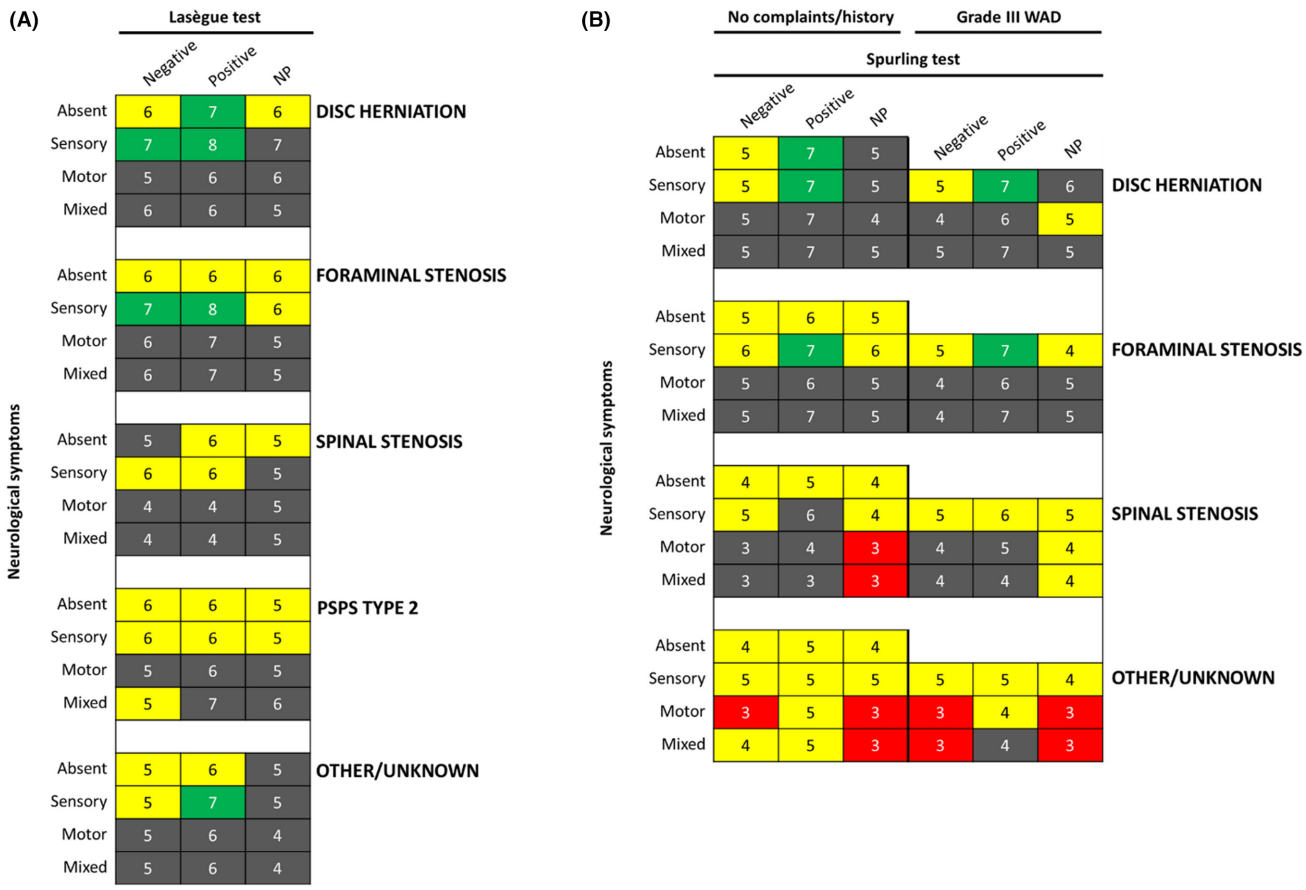

FIGURE 5 Appropriateness patterns of pulsed radiofrequency (PRF) for the treatment of chronic lumbosacral (A) and chronic cervical radicular pain (B). Numbers represent the median panel scores. Colors denote the appropriateness outcome (red=inappropriate; yellow=uncertain/equivocal; green=appropriate; gray=disagreement). NP, not performed; PSPS, persistent spinal pain syndrome; WAD, whiplash-associated disorder.

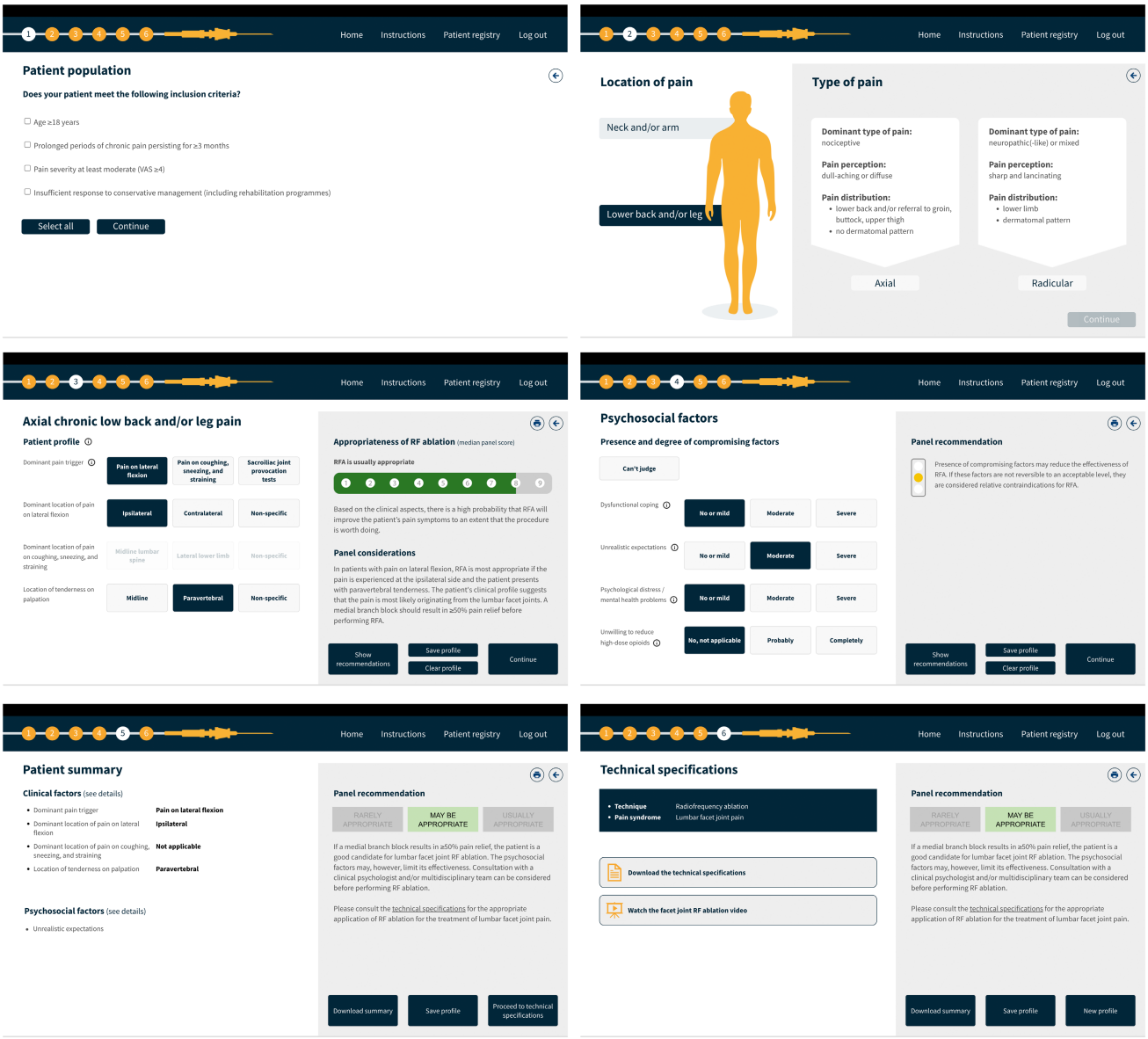

FIGURE 6 Multilayer format of the e-health tool: (1) patient population, (2) location and type of pain, (3) clinical factors, (4) psychosocial factors, (5) composite outcome, and (6) technical specifications.

selection criteria for RFA. For facet pain in the cervical region, there is moderate-quality evidence that supports the use of RFA of which the effectiveness may also be improved by the identification of patient selection criteria to reduce heterogeneity among studies and practices.[48,49] Despite the sometimes conflicting evidence, all 13 experts considered lumbar facet, sacroiliac, and cervical facet joint pain to be appropriate indications for RFA. In addition to these indications, RFA has been evaluated to treat axial pain from degenerative disc disease, but due to low-quality evidence and recommendations against its use, the majority of the experts did not consider intradiscal RFA or RFA of the ramus communicans to be an option for the treatment of discogenic pain.[13,50,51] Although some good results have been reported with intradiscal biacuplasty, which uses two cooled RF electrodes, evidence remains fairly limited and warrants further research.[52] Recent evidence suggests considering vertebrogenic pain in the differential diagnosis of discogenic pain for which basivertebral nerve RF ablation has emerged as a possible treatment option.[53,54] This RF treatment modality was, however, not yet considered by the panel because positive results have only been reported in very recent prospective clinical trials.[55,56]

Using the RUAM, the expert panel established patient-specific appropriateness statements for 75 clinical scenarios on RFA for the treatment of axial lumbosacral and cervical pain. Despite recent consensus practice guidelines, concluding that there are no factors that can reliably predict the outcomes of RFA for lumbar and cervical facet joint pain,[10,11] paravertebral tenderness and ipsilateral pain on lateral flexion consistently increased the

appropriateness of RFA in our panel study. There was even full agreement within the expert panel that patients with these characteristics can be considered good candidates for lumbar facet joint RFA. To differentiate lumbar facet from sacroiliac joint pain, a set of provocation maneuvers and motion tests (compression test, distraction test, Patrick's test, Gaenslen's test, thigh thrust test, Fortin's finger test, and Gillet test) can be performed.[57] If these tests are negative, it is unlikely that pain arises from the sacroiliac joints.[57] However, when pain is provoked by one or more of these tests, patients can be considered for sacroiliac joint RFA,[58] with paravertebral tenderness increasing its appropriateness in this study. Appropriateness figures were similar for chronic axial cervical pain whether or not there was a history of WAD (Grade I or II).

Due to the appropriateness of RFA being limited to well-selected patients, there was a relatively large number of scenarios for which the outcome was uncertain/equivocal. In these patients, RFA can, however, still be considered an option if a medial or lateral branch block results in ≥50% pain relief, confirming the diagnosis of facet or sacroiliac joint pain, respectively, but considering that outcomes may be limited due to presence of a concurrent myofascial, discogenic, or other coexisting pain component. Even for well-selected patients with an appropriate outcome, it is at this point still recommended to first apply a diagnostic/prognostic block to inform the decision on RFA,[10,11] although medial and lateral branch blocks are associated with a relatively high false-positive rate. This is particularly true if no confirmatory blocks are performed, which, nevertheless, come at the expense of a higher false negative rate.[10,11,59,60] The predictive value of diagnostic blocks could potentially be improved by the herein described appropriateness statements, although further research is needed to demonstrate if these criteria can indeed streamline patient selection for RFA.

For patients with back pain on coughing, sneezing, and straining, a diagnostic medial branch block was considered optional because the dominant pain trigger suggests the nature of the pain to be discogenic. If performed, a positive response would be suggestive of the presence of a coexisting facetegonic pain component, while a negative response would further point toward the diagnosis of discogenic pain. Despite part of the panelists considering RFA to be an option for the treatment of axial discogenic pain, the panel did not provide any further specifications on its use because the efficacy is yet unclear.[51,52] Until more supportive evidence becomes available, other treatment modalities may be more appropriate for treating patients with axial discogenic pain in the lumbosacral or cervical region.[1,51,52]

Chronic lumbosacral and cervical radicular pain

Compared with RFA, PRF does not create a lesion on the target nerve but instead alters pain signals secondary to an electromagnetic field.[61] Although the exact process by which PRF acts is not yet clarified, the possible mechanism of action seems to be related to the effect of the electromagnetic field on the neuronal transmission of pain through a process of neuromodulation. The application of PRF adjacent to the DRG showed biological actions on synaptic transmission, cell morphology, and the modulation of the expression of pain regulatory genes in the DRG and superficial dorsal horn of the spinal cord.[62–65] Due to its non-destructive character, PRF can be safely applied adjacent to the DRG for the treatment of lumbosacral and cervical radicular pain. Although (systematic) reviews generally support its use and effectiveness,[23,24,66,67] and increasing favorable evidence became available from recent smaller controlled studies,[25–27] few studies have also reported less supportive results.[68,69] In addition, despite recommendations in favor of PRF adjacent to the lumbar and cervical DRG,[13] different attitudes toward this treatment modality exist, which was also the case in our expert panel. Approximately one-third of the expert panel could be classified as "PRF non-believers" because they did not consider PRF to be a treatment option for radicular pain.

Similar to the patient-specific statements on RFA for the treatment of axial pain, the RUAM was used to generate 144 recommendations on PRF for different patient profiles with a (suspected) diagnosis of chronic lumbosacral or cervical radicular pain. Because of mixed opinions within the expert panel, there was much disagreement on the appropriateness of PRF for the included patient profiles. Nonetheless, the position of this expert panel is that PRF can be an appropriate option for carefully selected patients with chronic radicular pain due to herniated disc or foraminal stenosis on the condition that no motor deficit is present, which was the major determinant of disagreement between specialties and panelists with different attitudes toward PRF. For a long time, surgery was the only treatment option for patients with chronic refractory radicular pain, albeit with variable success and a considerable risk of complications.[52] Minimally invasive treatments can therefore provide an alternative to postpone or even completely avoid the need for surgical intervention, especially for patients who are reluctant to surgery.[52,70] This opinion seems to be endorsed by part of our panelists who considered PRF to be an option for the treatment of chronic radicular pain ("believers"), though minimally invasive treatments other than PRF exist with uncertainty on the most appropriate treatment modality for chronic radicular pain.[13,67,71] The appropriateness scores also learned that anesthesiologists and neurosurgeons may draw different conclusions from the results on radicular provocation tests (Lasègue and Spurling test), with anesthesiologists generally attributing higher appropriateness scores when these tests are positive. It should be noted that no single symptom reported during history taking or the result of a physical test is sensitive or specific enough to

confidently diagnose a lumbosacral radicular syndrome. Therefore, clinical guidelines recommend a combination of history and physical examination to reach a definitive diagnosis.[72]

Overall, appropriateness patterns were fairly similar between lumbosacral and cervical radicular pain, although additional analyses learned that neurosurgeons were firmly against the use of PRF to treat radicular symptoms in patients with a history of Grade III WAD. Anesthesiologists, however, did not exclude these patients from PRF, especially not if the pain was caused by disc herniation or foraminal stenosis and the diagnosis of radicular pain was confirmed by a positive Spurling test.

Due to the disperse opinions, 84% of the clinical scenarios on radicular pain had an uncertain/equivocal outcome. In contrast to axial pain, the expert panel did not recommend diagnosing radicular pain with a nerve root block. The main reason behind this opinion is safety because the needle then needs to be placed only once.

Educational e-health tool

The appropriateness outcomes were embedded in an educational e-health tool (https://rftool.org) that provides a stepwise approach to determine the eligibility of patients with chronic lumbosacral and cervical pain for (P)RF interventions. This process also includes a set of four psychosocial factors. In pain management, psychological factors are known to be important predictors of treatment outcomes, although research on the applicability for (P)RF is limited.[73–75] Therefore, the psychosocial factors used in the e-health tool were derived from a previous study on SCS, similarly applying an integrated approach to establish patient-specific recommendations for the (pre)selection of patients with chronic pain for SCS.[35] The validity of these psychosocial factors was confirmed in a recent retrospective study, showing a strong relationship between their severity with SCS outcomes.[76,77] Although the importance of considering a patient's psychosocial state for (P)RF patient selection remains to be determined, the expert panel agreed that the presence of severe, untreated factors, such as severe depression or bipolar disorder, should be considered absolute contraindications for (P)RF, irrespective of the clinical appropriateness outcome. However, when these factors can be remedied, (P)RF may be reconsidered.

In addition to patient selection, (P)RF outcomes are highly dependent on the technique. When (P)RF is considered an option, technical specifications on the application of the (P)RF intervention for the treatment of facet joint, sacroiliac joint, and radicular pain are accessible to the (P)RF performer. In an attempt to harmonize the RFA technique of the facet joints, best practices were developed in various consensus working groups.[10,11,78] These were made available in the e-health tool, though it should be mentioned that part of the expert panel reported using slightly different parameters. The application of RFA for the treatment of sacroiliac joint pain is further complicated by the existence of different techniques (linear strip versus periforaminal techniques).[79] The e-health tool only considers conventional thermal RFA and because no technique is superior, the choice remains to be the competence of the RF performer. For PRF, the most common treatment parameters used in prospective studies are summarized in the e-health tool. However, the technique would greatly benefit from efforts that aim to standardize its application.

Strengths and limitations

The study set-up fulfilled the RUAM requirements for panel size, geographic spread, and representativity of the disciplines most frequently involved in the decision-making around a therapeutic procedure.[32] Nevertheless, we acknowledge that the panel would have benefited from including orthopedic surgeons and neurologists, especially for the PRF indications. The results showed that the experts were largely in agreement on the scenarios pertaining to RFA for axial pain, while controversy around the use of PRF in the medical community was similarly reflected by the current expert panel. The panel not only "agreed to disagree" for some of the scenarios, but also shared similar opinions on scenarios related to the use of PRF for the treatment of radicular pain due to herniated disc or foraminal stenosis in the absence of motor deficit. In the RAND/UCLA approach, the process of (re)ratings is continued until no further increase in agreements can be expected.[32] In our study, this point was reached after three rounds.

CONCLUSIONS

This is the first study that attempted to establish patient-specific recommendations on the appropriate (pre) selection of patients with chronic axial and radicular pain in the lumbosacral and cervical region for either RFA or PRF. The recommendations were produced by a European multidisciplinary expert panel, using the validated RUAM, and embedded in an educational e-health tool (https://rftool.org) that may help to improve patient selection for (P)RF. Although the patient-specific recommendations were established by a panel of (P)RF performers with considerable practice experience, their applicability and validity should be confirmed in daily practice to demonstrate its usefulness not only for performing but also for referring physicians and to determine the predictive value of the panel recommendations for the outcomes of (P)RF interventions.

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CONFLICT OF INTEREST STATEMENT

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The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Figure S1.
Figure S2.
Figure S3.
Figure S4.
Figure S5.
Figure S6.
Figure S7.

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