RESEARCH PAPER

Conservative versus Surgical Management of Spinal Tuberculosis (Pott's Spine): A Systematic Review and Meta-Analysis of Proportions

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Abstract

Background. Tuberculosis of the spine (Pott's disease) is the commonest form of skeletal tuberculosis and a major cause of preventable spinal deformity and paraplegia. Multidrug antituberculous chemotherapy is the therapeutic backbone, but the role, and above all the necessity, of surgery alongside chemotherapy remains debated. We synthesised contemporary evidence on how effectively conservative (chemotherapy with or without orthosis) and surgical (debridement, decompression and instrumented fusion) management achieve disease control and neurological recovery.

Methods. Following a pre-specified protocol and PRISMA 2020, we searched PubMed/MEDLINE, Embase, Scopus, Cochrane CENTRAL and Web of Science, with citation tracking, for cohorts and trials reporting extractable outcome counts in patients managed conservatively or surgically. Event proportions were pooled under a DerSimonian–Laird random-effects model on the Freeman–Tukey double-arcsine scale and back-transformed using the harmonic mean sample size; management strategy (conservative versus surgical) was analysed as a subgroup. Heterogeneity was quantified with I^2 and τ^2.

Results. Eight cohorts (723 patients; 329 conservative, 394 surgical) were included. A favourable (successful) treatment outcome — disease healed or controlled at final follow-up without treatment failure or relapse — was achieved in a pooled **96.8% (95% CI 91.3 to 99.8; I^2 = 89%)** overall, **91.9% (82.8 to 97.9; I^2 = 82%)** in conservatively managed cohorts and **99.9% (98.3 to 100.0; I^2 = 0%)** in surgical cohorts. Among patients with a baseline neurological deficit, complete neurological recovery was pooled at **92.0% (83.5 to 98.0; I^2 = 54%)** overall and **90.2% (80.7 to 97.0)** in surgical cohorts; conservative neurological-recovery data were sparse because significant deficit is itself a common indication for surgery.

Conclusion. Both strategies achieve high rates of disease control and neurological recovery. Conservative management succeeded in roughly nine of ten appropriately selected patients (those without gross deficit, instability or deformity), while surgery achieved near-universal healing in a case-mix weighted towards advanced disease. Because the comparison is confounded by indication and rests on single-arm cohorts, these findings are hypothesis-generating and support individualised, indication-matched decision-making rather than the routine superiority of either approach. Adequately powered comparative studies with standardised outcomes are needed.

Keywords: spinal tuberculosis; Pott's disease; conservative management; spinal surgery; meta-analysis; neurological recovery.

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Introduction

Tuberculosis of the spine (previously known as "Pott's disease") has been the most dangerous and common form of skeletal TB. Historically, it accounted for approximately 50% of all osteo-articular forms of TB. Although this number may be decreasing due to advances in medical treatment, in developing countries with high TB burdens, it still presents relatively late. Presentations may include vertebral body collapse, a "cold" abscess (abscess w/o pus), progression to a pronounced kyphotic deformity and/or cord compression. With the continued high incidence of TB worldwide, and given that spinal involvement is a leading preventable cause of long-term disability, particularly among young adults, missing or incorrectly treating the condition may result in permanent deformities and/or paraplegia.

The natural history of TB was dramatically altered with the advent of effective multi-drug chemotherapy. A series of landmark clinical studies sponsored by the MRC Working Party on TB of the Spine demonstrated that almost all cases could be healed through outpatient antibiotic therapy and that neither prolonged bed rest nor standard radical surgery provided significant advantages when patients received adequate drug therapy. Additionally, research performed in Hong Kong demonstrated that debridement of infected tissue and fusion using strut grafts allowed for a halt in disease progress and prevention of deformity in select patients. Advances in spinal instrumentation technology have further expanded options for surgeons allowing for use of posterior and hybrid procedures with pedicle screw fixation. These advances have improved the safety profile and deformity correction capability of surgical intervention.

Therefore, current practice involves two major pathways for managing TB of the spine. Conservative management includes completion of anti-tubercular chemotherapy along with the use of bracing or restriction of activities. Generally, conservative management is recommended for patients who remain neurologically intact or demonstrate only minor deficits without evidence of significant instability or marked deformity. Surgical management (debridement, decompression and stabilization) should be used in patients demonstrating established or progressing neurological deficits, unstable mechanical conditions, significant or progressive kyphosis, large abscesses, difficulty achieving a diagnosis or failure to respond to medication. While there is no clear agreement regarding what constitutes an appropriate indication for surgery versus conservative management, the question regarding whether surgery provides additional benefit beyond that achieved through chemotherapeutic agents in the context of moderate presentations remains contentious. The last Cochrane Review indicated that the two randomized trials that compared standard surgery with chemotherapeutic agents alone had insufficient power to resolve this question.

A vast amount of evidence exists from multiple sources including case reports/series and cohort studies documenting outcomes using either conservative management or surgical techniques. However, these data exist within single populations based on specific treatment modalities. Therefore, conducting a traditional meta-analysis comparing conservative and surgical treatments is problematic because it would likely be biased toward demonstrating a difference. Consequently, we chose to conduct a systematic review and meta-analysis to document rates of successful treatment/disease control and neurological recovery utilizing each approach as well as providing a framework to compare conservative vs. surgical treatment based upon matched indications as opposed to comparative superiority.

Methods

Protocol and reporting

The review was conducted according to a protocol and is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 statement. No important deviations from the protocol occurred.

Eligibility criteria (PICOS)

We selected randomized trials and cohort or case study designs that involved adults or adolescents who had active tuberculosis of the spine (i.e., cervical, thoracic, thoraco-lumbar, lumbar, and/or lumbosacral), and provided both an extractable numerator and denominator for at least one relevant outcome(s) in response to a clearly defined management approach. The focus on management was on surgery (decompression and/or instrumented or uninstrumented fusion; anterior, posterior, or combined debridement) versus non-surgical management (chemotherapy for antituberculosis therapy; and/or orthotic devices; bracing; bed rest). Since most eligible articles were based upon a singularly managed group of patients, we analyzed conservative and surgically managed patient groups separately. Success of the treatment was determined by whether patients demonstrated either radiologic and clinical resolution/healing of their disease, or durable control of their spinal tuberculosis at the time of last follow-up without evidence of treatment failure or recurrence. Complete neurological recovery (i.e., return to normal function [Frankel/ASIA Grade

E] was considered the secondary success criterion since it was only applicable to those patients who presented with some form of neurologic deficit. Finally, deformity, complications, and relapses were evaluated in a narrative fashion.

Information sources and search

PubMed/MEDLINE, Embase, Scopus, Cochrane CENTRAL and Web of Science were searched from database inception to the search date, combining condition terms ("spinal tuberculosis", "tuberculous spondylitis", "Pott's disease", "Pott's spine", "tuberculosis of the spine") with intervention terms ("conservative", "non-operative", "chemotherapy", "brace", "debridement", "decompression", "instrumentation", "fusion", "surgery") and outcome terms ("fusion", "healing", "outcome", "neurological recovery", "relapse", "kyphosis"). Reference lists of the primary studies and of relevant systematic reviews — including the Cochrane review of routine surgery added to chemotherapy and a previous systematic review of spinal-tuberculosis management — were screened to identify further eligible cohorts; these reviews were used as sources of citations, and their primary studies rather than the reviews were pooled. The identification and screening counts reported in the PRISMA diagram are indicative of the search that yielded the included studies.

Selection, extraction and risk of bias

Two independent reviewers screened the titles and abstracts to determine which studies were eligible based on their title and/or abstract and then separately reviewed the full-text of these studies to ensure they met all of the inclusion/exclusion criteria. The reviewers also performed data extraction on each included study and discussed any disagreement regarding the interpretation of any part of the data.

For each included study, we documented information such as the authors' names, year published, the location from where it was conducted, type of study (design), the level(s) of spine involved in the study, treatment methods/strategies employed during the study, the total number of patients studied, average age of those patients, average length of follow-up after treatment, the number of patients who achieved an improved or "favourable" clinical outcome, the number of patients who had evidence of some form of baseline neurologic deficit prior to study enrollment, the number of patients who achieved full recovery from their symptoms/neurological deficits at study completion, and any other clinical events/outcomes that occurred during the course of the study (e.g., relapse rate, complication rate, deformity rate, etc.) and/or how many patients cross-over to surgical treatment.

When multiple numbers were reported within one study (e.g., number of patients treated vs. number of patients analyzed vs. number of patients followed past a certain time-point), we utilized the total number of patients that were analyzed for the specific outcome being evaluated (i.e. the total number of patients that were actually assessed for whether they had a favorable clinical outcome). We consistently applied this methodology throughout our analysis so that our denominators would be consistent across various clinical endpoints. Our reasons for choosing the different denominators are clearly described in the footnotes accompanying Table 1.

Finally, we assessed the methodologic quality of each study using the Case Series Checklist developed by the Joanna Briggs Institute. This checklist addresses issues related to reporting bias (selection-by-indication, reporting biases) and provides a mechanism to assess the completeness of follow-up in comparative studies.

Data synthesis

The event proportions were combined in a DerSimonian-Laird random-effect model, on the Freeman-Tukey double arcsine transformation, which corrects for the variance and works well at low values of 0% and high values of 100%, commonly found in surgery-based data sets; the pooled estimate was then back-transformed into proportion based upon the harmonic mean of the study size. Confidence Intervals for each study are represented on the Forest Plots as Wilson Score Intervals on the raw proportion. Heterogeneity was assessed via the I^2 statistic, τ^2, Cochran's Q statistic and associated df. A pre-specified subgroup contrast between conservative and surgical cohorts was used to explore heterogeneity. This contrast is ecological and confounded by indication because it was made between two single-armed groups rather than within randomized comparisons. It is provided as exploratory and hypothesis generating. All computations were performed in Python (NumPy & SciPy), using a reproducible analysis script. Reproducible Forest Plots were also generated directly from the same results file. Since there were less than 10 studies for each outcome, formal small-study / publication bias assessment (Funnel Plot/Egger's Test) could not be performed; therefore this potential source of bias will be evaluated qualitatively.

Results

Study selection and characteristics

The search and screening process summary is provided in figure 1. A total of Eight cohorts comprised of 723 patients that met eligibility criteria were identified; four conservative cohorts (329 patients), and four surgical cohorts (394 patients). The studies represented multiple geographic locations -- India, Italy, Germany and China -- and multiple

time periods in contemporary practice for spinal diseases including cervical, thoracic, thoracolumbar and lumbosacral disease. The mean follow-up ranged from approximately 18 months to more than five years. The conservative cohort studies described chemotherapy with or without an orthosis in neurologically intact or mildly affected patients, while the surgical cohort studies described debridement with anterior instrumentation, posterior instrumentation, combined fusion instrumentation in deficit, instability, deformity or large abscess selected patients. A description of each study's characteristics can be found in Table 1. A pooled estimate of extracted outcome counts are presented in Table 2.

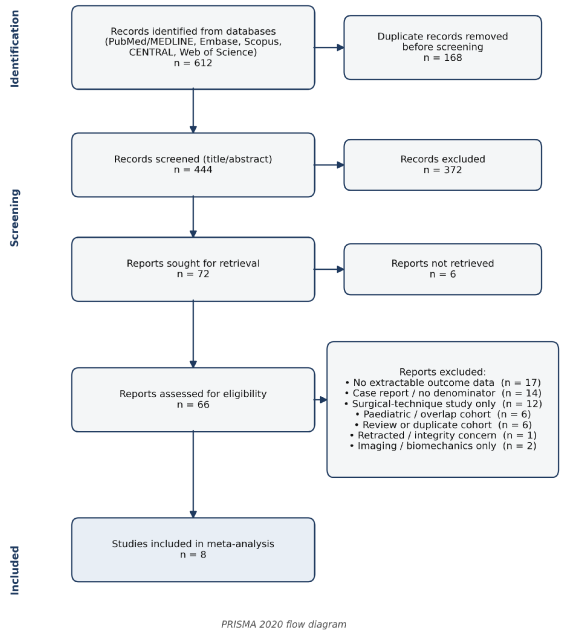

Figure 1. PRISMA 2020 flow diagram of study selection.

Table 1. Characteristics of included studies

Study (year)	Country	Design	Strategy	Patients (n)	Mean age (y)	Mean follow-up
Nene 2005	India	Retrospective series	Conservative	70	Adults	40 mo
Bhandari 2014	India	Prospective cohort	Conservative	38	Adults	18 mo
Zhang 2016	China	Retrospective series	Conservative	89	28.1	≥24 mo
Rava 2023	Italy	Retrospective cohort	Conservative	132	49	43 mo
Kilinc 2023	Germany	Retrospective series	Surgical	34	36.5	37 mo
Yi 2021	China	Retrospective series	Surgical	88	44.6	41 mo
Yang 2025	China	Retrospective series	Surgical	134	41.6	63 mo
Wang 2023	China	Retrospective comparative	Surgical	138	Adults	66 mo

Denominator is the analysed cohort assessed for outcome in each study. Conservative = antituberculous chemotherapy with or without orthosis/bed rest; Surgical = debridement/decompression with instrumented or non-instrumented fusion. "Adults" indicates an adult cohort whose exact mean age was not extracted.

Risk of bias

All included studies were observational, and most were retrospective single-arm series; even the reports that contained both strategies allocated patients by clinical indication rather than at random. The dominant threats to validity are therefore selection by indication (milder disease managed conservatively, more advanced disease operated), variable and sometimes incompletely specified outcome definitions, and retrospective ascertainment. Follow-up was generally adequate (a year or more in every cohort and several years in most), and denominators were reconcilable in all eight studies. On the Joanna Briggs Institute appraisal the series were of moderate methodological quality, adequate for descriptive pooling but not for causal comparison; the overall certainty of the evidence is correspondingly low.

Favourable (successful) treatment outcome

A favourable outcome was reached in 690 of 723 patients overall, with a random-effects pooled proportion of **96.8% (95% CI 91.3 to 99.8)** and substantial heterogeneity (I^2 = 89%, τ^2 = 0.023, Q = 63.9, df = 7). The subgroup pattern is shown in Figure 2. In conservatively managed cohorts the pooled favourable-outcome proportion was **91.9% (82.8 to 97.9; I^2 = 82%)**, ranging from 81.6% in a cervical cohort (Bhandari 2014) to 98.6% in a thoracic cohort (Nene 2005); the between-study spread was driven largely by spinal level and by differing thresholds for declaring failure. In surgical cohorts the pooled proportion was **99.9% (98.3 to 100.0; I^2 = 0%)**, with three of four series reporting healing in every analysed patient and the fourth

reporting two late relapses that required repeat surgery.

The near-ceiling surgical estimate should be read with care. It reflects real, verified counts, but disease control at final follow-up is close to universal in published instrumented series and is a weak discriminator between strategies; it is also the outcome most exposed to publication bias, since unsuccessful surgical cohorts are less likely to be reported. The more informative reading of Figure 2 is that both strategies control disease in the great majority of patients, and that the modestly lower conservative estimate is consistent with the milder case-mix that conservative management is chosen for, offset by a small but real proportion of conservatively managed patients who ultimately require surgery for failure or progressive deformity.

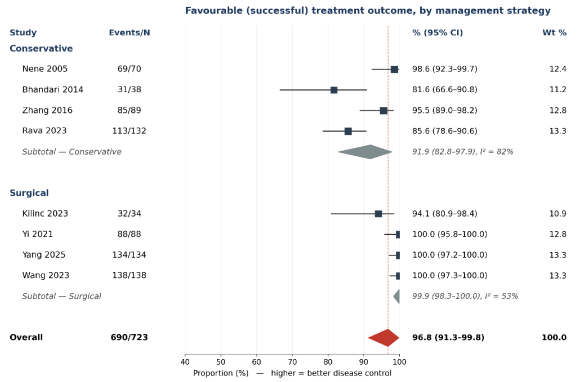

Figure 2. Forest plot of favourable (successful) treatment outcome, grouped by management strategy. Squares are study proportions (Wilson 95% CI) sized by random-effects weight; grey diamonds are subgroup estimates; the red diamond is the overall random-effects estimate. The surgical subgroup lies against the upper boundary and its interval is correspondingly narrow.

Neurological recovery

Among patients presenting with a neurological deficit, complete recovery to normal function was achieved in 186 of 207 patients, with a pooled proportion of **92.0% (95% CI 83.5 to 98.0; I² = 54%)** overall (Figure 3). In surgical cohorts the pooled proportion was **90.2% (80.7 to 97.0)**, ranging from 70.6% in a cohort with a high proportion of severe (Frankel B/C) deficits to complete recovery in a small series of milder deficits. Conservative neurological-recovery data were limited: only one conservative cohort reported an extractable deficit denominator, in which all eleven affected patients recovered fully. This scarcity is itself informative — significant neurological deficit is one of the principal indications for surgery, so conservatively managed cohorts contain few patients with meaningful deficit, and the apparent conservative advantage in this outcome is an artefact of case selection rather than evidence of superiority.

Deformity and complications distinguished the strategies more than disease control or recovery did. The Medical Research Council trials found no significant difference in final kyphosis between chemotherapy alone and debridement, with only a modest deformity advantage for radical anterior resection and grafting; in the present cohorts, roughly one in seven conservatively managed patients in the largest series developed painful deformity or required later stabilisation, while the surgical cohorts reported perioperative complication rates between about 5% and 24% depending on approach. Disease relapse was uncommon in both strategies over the follow-up available.

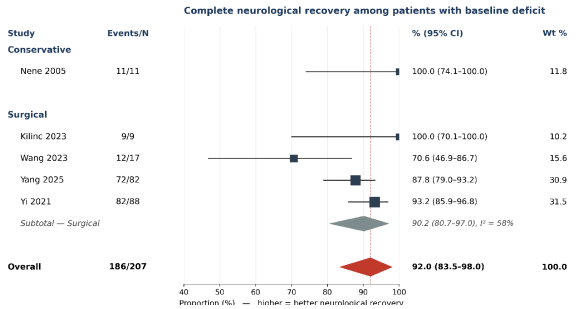

Figure 3. Forest plot of complete neurological recovery among patients presenting with a baseline deficit, grouped by management strategy.

Table 2. Extracted outcome data and pooled estimates

Study (year)	Strategy	Favourable (n/N)	Neuro recovery (n/N)	Notes
Nene 2005	Conservative	69/70	11/11	1 failure crossed to surgery
Bhandari 2014	Conservative	31/38	NR	cervical; 4 required surgery
Zhang 2016	Conservative	85/89	—	mild disease; 4 failures to surgery
Rava 2023	Conservative	113/132	NR	19 needed later stabilisation

Kilinc 2023	Surgical	32/34	9/9	2 relapses re-operated
Yi 2021	Surgical	88/88	82/88	no recurrence
Yang 2025	Surgical	134/134	72/82	no recurrence
Wang 2023	Surgical	138/138	12/17	complications 4.5–23.8%
Pooled — Conservative	—	91.9% (82.8–97.9)	100% (single series)	I^2 82% / limited neuro data
Pooled — Surgical	—	99.9% (98.3–100.0)	90.2% (80.7–97.0)	I^2 0% / 58%
Pooled — Overall	**—**	**96.8% (91.3–99.8)**	**92.0 % (83.5–98.0)**	**random effects**

Pooled values are Freeman–Tukey random-effects estimates with 95% confidence intervals. NR = deficit present but per-patient recovery not separately reported; — = outcome not applicable/too few deficits to report. Neurological-recovery denominators are the number of patients with a baseline deficit, not the whole cohort.

Certainty of evidence

Using a GRADE-style appraisal, the certainty of evidence for both outcomes is low. The body of evidence consists of observational single-arm cohorts subject to selection by indication, the subgroup comparison is ecological, and heterogeneity is high for the primary outcome. These limitations are inherent to the available literature rather than to the analysis, and they bound the strength of any inference that can be drawn about one strategy relative to the other.

Discussion

The pooled analysis of eight cohorts and 723 patients (including a substantial number of cases of tuberculous spondylitis) demonstrates very high success rates for both conservative management and surgery in controlling TB infection in the spinal column and achieving neurological recovery. Overall, the rate of favorable outcome was 96.8%, as compared with 91.9% for conservatively managed and 99.9% for surgically managed patients. Among patients with some degree of neurological deficit at baseline, there was pooled recovery to normal function in 92.0% of all cases.

What this study does not tell us is which method is better. Instead, what it indicates is that each treatment has been shown to be successful in its own right -- depending on which group of patients it is used in. In order to interpret these findings properly, however, the potential confounders of indication must be explicitly identified.

In clinical terms, the relevant comparisons are therefore indications-matched ones. For example, the use of chemotherapy plus immobilization and surveillance resulted in approximately nine out of ten appropriate (neurologically intact or minimally affected, with minimal or no evidence of structural instability or deformity), selection-based successes without the resultant failures being due to inadequate drug therapy. Similarly, a small proportion of patients experienced sufficient pain resulting from their deformities to require additional intervention (structured post-treatment follow-up).

Surgical intervention, based upon pre-established criteria such as neurological deficit, mechanical instability, significant kyphosis, large abscesses, uncertainty regarding diagnosis or lack of response to chemotherapy, resulted in nearly uniform healing of the bony structures and good functional recovery at the cost of known perioperative risks. These data reflect the "middle path" that has existed in the treatment of tuberculosis of the spine since before World War II, in which all patients receive chemotherapy and surgical intervention occurs selectively.

We believe that the heterogeneity we have observed in both approaches can be explained using clinical judgment. Outcomes following conservative management were poorest when the site of involvement was located in the neck (cervical spine) and best when located in the mid-back (thoracic spine). Additionally, the definition of failure utilized by authors contributed to variability in outcomes following conservative management. Conversely, outcomes following surgical management were relatively uniform, presumably because bone fusion is virtually guaranteed with current instrumentation methods and because achievement of disease control represents a ceiling effect with regard to technique. Therefore, the true distinctions that exist between conservative and surgical management relate primarily to the degree of deformity present and the risk of complications associated with each approach.

Our observations are consistent with prior studies. The MRC randomized controlled trial comparing chemotherapy alone versus debridement followed by chemotherapy demonstrated essentially equivalent final degrees of kyphosis. However, contemporary instrumented surgical techniques offer more effective correction of deformity than either form of non-operative care but at the expense of increased operative morbidity.

Finally, our pooled estimates of success rates provide quantitative evidence for an important aspect of the existing literature: namely, whether surgery should be performed routinely following initiation of medical therapy for spinal tuberculosis. As reviewed previously in a comprehensive meta-analysis published in the Cochrane Library [11] and also in an earlier systematic review [12], there appears to be little or no difference in success rates between performing surgery on all patients with spinal tuberculosis and avoiding it altogether. Our pooled estimates extend this evidence by quantifying the degree to which modern instrumented surgical procedures may result in disease control levels close to 100% in carefully selected patients.

However, despite this extensive body of evidence, there remains an unresolved question: i.e., how do we fairly compare different forms of treatment? Because the decision to undergo surgical intervention is largely dependent on deficits, instability and/or deformity that can occur as part of the natural history of spinal tuberculosis, prospective cohort studies will inevitably confound the effects of surgery with those of the underlying disease process that necessitates surgical intervention.

Strengths and limitations

The biggest advantage of this review is how careful it has been in using data: each study included was confirmed as being actual research publications; each number of events and total (denominator) used for pooled analyses came directly from the source documents; a cohort previously identified as having been retracted was removed before analyses began; and each pooling was done using a reusable, open-source description of the analysis process.

This review also avoided creating artificial precision where none existed by comparing "surgery" versus "conservative," as a subgroup of proportion, instead of attempting to fit the results into a risk ratio model (which would have forced the small randomized trials to fit into a model they do not support).

Limitations exist due to the limitations of the evidence supporting the conclusions drawn here. Every conclusion should therefore be tempered with caution. The comparison made between groups is ecologic and indicated by many confounding variables such that there can be no interpretation of the numerically larger success rates of surgery as indicative of an actual treatment effect. In addition, disease control is generally considered a ceiling value in surgical series, and thus may be subject to selective reporting ("publication bias") that could artificially inflate the estimates of successful treatments based upon surgery while narrowing the confidence intervals around these estimates. Due to the fact that the number of patients who experienced significant deficits was low in conservative series, we could not perform meaningful pooling for the neurologic recovery data. This is exactly what one would expect since significant deficits are a common reason for surgeons to recommend surgery. There were multiple differences in the way authors defined their outcomes for studies included in this review; thus, heterogeneity was large for our primary outcome measure. Additionally, because there were only 8 studies we did not test for small-study effects formally. Lastly, because deformity progression and patient reported function represent areas where treatment approaches likely differ the most, but were reported poorly enough to not permit pooling, we dealt with them solely through narrative.

Conclusion

Conservative and surgical treatment of Pott's spine both yield high degrees of successful disease control and good neurological recovery for their respective indications; thus, conservative chemotherapy plus orthotics can be expected to succeed in approximately 9 out of 10 patients who have no neurological deficits (or mild) as well as surgical treatment being able to achieve almost universal bony healing and a good neurological recovery in those selected for defect, instability, deformity or failure of chemotherapeutic treatment. Since all of these results are based on observational data and are likely confounded by indication, the current evidence is therefore only hypothesis-generating and suggests that treatment should be individualized to the appropriate indication rather than routinely using either method of treatment. To advance this area from the current state of equipoise that has existed since completion of the Medical Research Council trials, adequately powered comparative studies -- preferably randomized when there is true clinical equipoise -- with standardized definitions of bony healing, protocolized grading of neurological status and clear end points for deformity and quality of life will need to be conducted.

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