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Management of displaced fractures of the waist of the scaphoid: Meta-analyses of comparative studies

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ABSTRACT

Introduction: Scaphoid fractures with displacement have a higher incidence of nonunion that can cause pain and reduced movement, strength and function. The aim of this study was to review the evidence available and establish the risk of nonunion associated with management of displaced fractures of the waist of the scaphoid.

Methods: Electronic databases were searched using the Medical Subject Headings (MeSH) controlled vocabulary (scaphoid fractures, AND'd with displaced, or nonunion, or non-healing or cast immobilisation, or plaster or surgery). At present, there are no randomised, controlled trials or studies comparing fixation to plaster cast treatment of displaced fractures of the scaphoid. The search was therefore limited to observational studies of displaced fractures of the scaphoid treated in a plaster cast (non-operative group) or fixed surgically (operative group). The criterion for displacement was limited to gap or step of more than 1 mm. In the non-operative group, we compared the outcome of displaced and undisplaced fractures of the waist of the scaphoid treated in a plaster cast. In the operative group, contingency table analysis was used to calculate the odds ratio of nonunion with plaster treatment compared to surgery.

Results: In the non-operative group, seven studies were included in a meta-analysis with a total of 1401 scaphoids. Ninety-three percent (1311 scaphoids) of these scaphoid fractures healed in a plaster cast. A total of 207 (15%) of all scaphoid fractures showed displacement of at least 1 mm (gap/step) between fracture fragments. Nonunion was identified in 18% (37/207) of displaced scaphoid fractures treated in a plaster cast. The pooled relative risk of fracture nonunion was 4.4 (95% confidence interval (CI): 2.3–8.7; $p = 0.00$; $I^2 = 54.3\%$). In the surgical group, we identified six observational studies in which 157 'displaced' fractures of the scaphoid were surgically fixed. Only two of these fractures did not heal. The odds of nonunion were 17 times higher with plaster cast treatment than surgery.

Conclusions: Displaced fractures of scaphoid have a four times higher risk of nonunion than undisplaced fractures when treated in a plaster cast, and the patients should be advised of this risk. Nonunion is more likely if a displaced fracture of the scaphoid is treated in a plaster cast.

Introduction

Scaphoid fractures are common in young men and occur due to a fall on the outstretched hand or sudden forced dorsiflexion of the wrist.[1] A total of 85–90% of these fractures unite in a below-elbow plaster cast but those with displacement have a higher incidence of nonunion[2,3] and may unite in a humpback position.[4] A displaced fracture is one in which the fragments have moved from their anatomical position or there is movement between them when stressed.[5,6] The assessment of displacement with radiological methods is difficult. The four bony features that suggest displacement are translation, gap, angulation and rotation. A scaphoid fracture is considered as displaced if the offset (step off) or gap is 1 mm or greater on postero-anterior or oblique scaphoid radiographic views. Scaphoid angulation also indicates displacement of fracture fragments but it is extremely difficult to quantify the intrascaphoid angulation on radiographs due to the overlap of the other carpal bones. When radiographs are used to measure displacement, the reported incidence of nonunion varies between 14%[2] and 92%.[7] This variation could reflect the population studied and the lack of standardisation of the definition of displacement. Computed tomography in the longitudinal axis of the scaphoid is a more reliable method for determining scaphoid displacement[8] but can be inaccurate and variable even for normal scaphoids, as accuracy of measurement depends on the slice thickness and the plane of imaging.[9]

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At present, there is no randomised trial comparing healing rates of displaced versus undisplaced scaphoid fractures. There is a greater risk of nonunion if a displaced scaphoid fracture is treated in a plaster cast but we do not know how much greater this risk is. Surgical treatment is advocated for displaced scaphoid fractures although there are little available data to counsel patients about the risk of nonunion. Our aim was to review the evidence available on treatment of displaced scaphoid fractures and to measure the relative risk of nonunion associated with displacement. We also calculated the sample size for future randomised trials on surgical management of displaced fractures of the waist of the scaphoid.

Methods

Articles were sourced from MEDLINE (1947–2011), EMBASE (1980–2011), Cumulative Index to Nursing and Allied Health Literature (CINAHL) and the Cochrane controlled trials register electronic databases, Thomson Scientific Web of Science (1993 through October 2011) and Elsevier Scopus (inception through October 2011). The search was undertaken with the help of a clinical librarian who has experience in searching electronic databases using the Medical Subject Headings (MeSH) controlled vocabulary. The primary terms were scaphoid fractures, AND'd with displaced, or nonunion, or non-healing or cast immobilisation, or plaster or surgery. Subheadings (such as follow-up and complication) were attached to the subject heading to focus the results fully on treatment. There was no restriction on language. All results were downloaded into EndNote, a bibliographic database manager, and duplicate citations were identified and removed. Authors independently assessed the eligibility of identified studies. Any study that could be relevant based on findings described in the abstract was obtained, and the full text was reviewed. Bibliographies and review articles were reviewed manually for additional citations. Abstracts and unpublished work were excluded. Authors were not contacted.

We found no randomised or case studies where surgery was compared to plaster treatment of displaced fractures of the waist of the scaphoid. Hence, the search was limited to observational studies. The articles identified could be broadly classed into two groups (surgical and non-surgical) depending on the method of fracture management. In the non-surgical group, observational studies with consecutive cases including both displaced and undisplaced fractures of the waist of the scaphoid treated in a plaster cast were selected, as this would provide the best data for a meta-analysis (Table 1). In the surgical group, as there were no comparative studies available with treatment of the fracture using internal fixation and cast treatment, meta-analysis could not be used for analysis and a two-way contingency table was used to calculate the odds ratio of nonunion with plaster cast treatment compared to surgery.

Inclusion criteria

1. original articles with cases of displaced fractures of the waist of the scaphoid,
2. displacement noted on radiographs or computed tomography (CT) scans measured as translation or gap between fragments and
3. the studies reporting the rate of fracture union as an outcome.

Exclusion criteria

1. fractures of the base or proximal pole of the scaphoid and
2. duplicate publications of any type or articles based on a subset of data from other bigger series.

Data collection

A data collection form was developed and used to retrieve information on relevant results. Authors independently extracted and recorded data on a predefined checklist. The retrieved datasets included: study characteristics (i.e., country and year of study), plaster type, interventions, surgery, outcome definition, sample size, the number of patients with displaced fractures and those with undisplaced fractures and the number of patients with nonunion in each group. A nonunion was defined as a scaphoid fracture that had not healed as defined by the author(s) of each study. All studies defined nonunion as a clear gap at the fracture site on radiographs.

A qualitative assessment of the included studies was not conducted, as there are at present no scoring systems available for the appraisal of comparative studies. We assessed the other confounding factors that could introduce heterogeneity in the studies. The studies were similar for mean age and sex distribution (Table 2). The main meta-analytic comparison was based on the rate of fracture union in patients with displaced scaphoid waist fracture versus those with undisplaced fracture. The number of fractures that united was extracted from all studies. We pooled studies using the DerSimonian–Laird random effects model[10] (and constructed corresponding Forest plots) that recognises studies as a sample of all potential studies and incorporates a between-study random effect component to allow for between study heterogeneity. Pooled adjusted effect estimates were obtained by combining the estimates of log (effect estimate) from each study. We obtained the overall I^2. The I^2 statistic defines the variability percentage in effect estimates that is due to heterogeneity rather than due to chance – the larger the I^2, the greater the heterogeneity. All analyses were conducted using Stata 10 (StataCorp LP, College Station, TX, USA). A random-effects model was fitted. The analysis used the number of events of fracture union to obtain the odds ratio of one group relative to the other group. As one study, that by Bhat et al.,[3] had a 'zero-cell' as all fractures in the undisplaced group healed, it was shown as a point outside the triangle in the funnel plot and the conventional 'continuity correction' was used and 0.5 (half a person) was added to each of the four counts to allow for the meta-analysis.

Results

The search strategy yielded 147 publications of which 110 publications included review of undisplaced fractures alone. As many as 22 were not eligible, as they were expert opinions or review articles based on previous studies. We systematically searched the reference list of all eligible articles and identified no additional study that was not captured with our search strategy. In the non-surgical group, eight articles were included in the meta-analysis as they had consecutive series of patients and nonunion was reported after plaster cast treatment for both displaced and undisplaced fractures. In the surgical group, seven articles (Table 3) were identified for inclusion in the study but they did not include a comparative group; hence, these studies were excluded from the meta-analysis and were assessed with a descriptive analysis.

In the non-surgical group, the studies had initially included 1895 patients with scaphoid fractures but 365 patients were lost to follow-up. All patients were adults and had sustained a scaphoid waist fracture confirmed on a radiograph. Non-surgical treatment included a below-elbow plaster (Colles') cast, long and short thumb spica cast or short thumb spica cast. The length of immobilisation in the cast varied from 6 to 10 weeks between the studies. The definition of nonunion used in the studies was a clear gap seen at the fracture site on radiographs after 12 weeks.

Table 1
Studies included in the meta-analysis.

Study	Total *N*	Displaced *N*	Total union	Displaced union	Method of treatment	Definition of displacement gap/step		Follow-up (years)	Complication nonunion (%)	Comments
Bohler[11] (English translation JHSe[12])	580	70	557	63	Dorsal plaster splint (thumb free or thumb included)	Gap		7.9	10	Nonunion in 5.7% (2 of 35) displaced fracture treated with thumb free plaster, 14.3% (5 of 35) of thumb included plaster
Leslie Dickson[13]	222	7	211	5	Below elbow plaster (thumb in)	Gap at one week	Displacement in plaster	8	28	Nonunion did not occur in fractures with initial displacement but 18% of fractures where fractures displaced in plaster nonunited
Alho and Kankaanpaa[14]	100	23	92	18	Below or above elbow plaster	Axial/transverse displacement	>1 mm	2	21	6 of 8 nonunion had sclerosis of proximal pole
Cooney et al.[6]	45	10	37	7	Long or short arm cast	>1 mm offset	>45° scapholunate angle, >15° luno-capitate angle	1–4	33	3 nonunion in displaced group associated with displaced intra-articular distal radius fracture
Thorleifsson[15]	112	14	105	8	Plaster scaphoid cast	>1 mm offset		4–8	28	Mean plaster time for displaced fractures 9 weeks
Clay et al.[2]	292	74	263	63	Below elbow/ scaphoid cast	>1 mm offset	Comminution or (Herbert 2b)	0.5	15	Two centre prospective study
Bhat et al.[3]	49	9	46	6	Below elbow plaster (thumb free)	Gap	Lateral intrascaphoid angle, height to length ratio	1	33	MRI scan used for calculation of intrascaphoid angulation
Eddeland et al.[7]	134	25	88 of 92 fresh fractures (20 of 38 nonunions)	2	Long or short arm cast (ORIF for pseudoarthrosis)	>1 mm dislocation		1–10	92	Initial cohort with 92 fresh fractures (88 healed in plaster cast) and 38 nonunions (27 cases with age of fracture >1 year)
Total plaster treated	1535	232	1399	172						

Table 2
Demographic data for studies included in meta-analysis.

Study	Total patients	Lost to follow-up	Sex		Mean age (years)
			Male	Female	
Bohler[11] (English translation JHSe[12])	732	154	670	62	33
Leslie Dickson[13]	222	0	190	32	27
Alho and Kankaanpaa[14]	100	0	84	15	31
Cooney et al.[6]	45	0	NA	NA	NA
Thorleifsson[15]	158	48	85	25	25
Clay et al.[2]	392	100	222	70	30
Bhat et al.[3]	50	1	NA	NA	NA
Eddeland et al.[7]	196	62	112	22	25

NA: not available.

Table 3
Studies including surgical management of displaced fractures of scaphoid.

Study	Total *N*	Displaced *N*	Total union	Displaced union	Method of treatment	Definition of displacement gap/step	Follow-up (years)	Complication nonunion (%)	Comments
Trumble et al.[16]	35	35	35	35	Open Herbert wipple/AO screw bone graft	1 mm gap	NA	0	1 prominent screw, 2 wire removal
Rettig et al.[17]	14	14	13	13	Herbert screw 8 multiple *k* wires 6 open fixation and scaphoid cast	1 mm gap	2.2–3	7	1 nonunion, trispiral tomography postoperative, 10 marked Comminution (bone grafts used), 3 associated distal radius fracture
Shih et al.[18]	15	15	15	15	Percutaneous, arthroscopy assisted screw fixation	>1 mm		0	Ligament and chondral injuries found on arthroscopy
Chao-Yu Chen[19]	97	11	97	11	Closed reduction and percutaneous pinning	>1 mm offset	1.6	0	1 local erythema
Martinache and Mathoulinb[20]	37	15	37	15	Palmar, arthroscopy assisted screw fix	>2 mm offset	2	0	5 patients had residual pain, screw removal, pin breakage
Slade and Gillon[21]	126	67	125	66	Open/percutaneous fixation	Gross displacement, >2 mm	1–4	1	1 delayed union, 1 OA needing arthrodesis
Total surgically treated	324	157	322	155					

A total of 232 (15%) of the 1535 scaphoid fractures were displaced with more than 1 mm of displacement between fragments (Table 1). Eddeland et al.[7] reported a nonunion rate of 92% in scaphoid fractures (23 of 25 fractures) with displacement greater than 1 mm compared to 19% pseudoarthrosis in 93 fractures with less than 1 mm displacement. Full text review of this article revealed that all that did not unite were not immobilised for the first 4 weeks (defined as age of fracture); hence, the reported high incidence reflected inadequate initial treatment and early bone resorption. Further, including the Eddeland article in the meta-analysis showed a huge odds ratio of 253. The Forrest plot showed publication bias and the result of the 'heterogeneity test' showed that only random effects DerSimonian–Laird models are valid in this analysis, which meant that the studies are significantly different with regard to results. We therefore decided to do the meta-analysis excluding the data from this article. None of the other studies showed such a pattern.

When the paper by Eddeland et al.[7] was excluded from the meta-analysis, the pooled relative risk of nonunion for displaced fractures versus undisplaced fractures of the scaphoid treated in a plaster cast was 4.4 (confidence interval (CI) 2.2–8.7) (Fig. 1) and pooled odds ratio was 5.5 (CI 2.5–12.3) (Fig. 2). The value of I^2 for this analysis was 54%, which showed that there was some evidence for variation in effect size attributable to heterogeneity among the studies rather than due to chance alone ($p = 0.04$). Hence, the 'random effects' calculation was used to allow for the possibility that the results from the separate studies differ more than those that would be expected by chance. The funnel plot (Fig. 3) gave no strong visual indication of publication bias having affected the selection or availability of the reported results.

If the studies of pre-1980 are deleted from the meta-analysis, then the relative risk rises even higher to 5.5 with tight CIs (1.80–14.8). It can be argued that some included studies were prior to the development of routine cross-sectional imaging technology. However, even if all the studies before 1990 are removed, the relative risk remains at 5.04 and CIs become wider (0.35–72.6).

In the surgical group, there were seven published case series[16–22] of surgical fixation of displaced fractures of the waist of the scaphoid with headless screws (Table 4). Two studies are based on the same data reported in two separate publications.[21,22] As four of these studies did not have a comparative group and showed a 100% union rate after surgical fixation, a meta-analysis was not possible. Only two of 157 cases of displaced fractures of the scaphoid included in this study failed to heal after surgical management. A two-way contingency table analysis showed an odds ratio of 16.9 of nonunion with plaster cast treatment compared to fixation ($p < 0.001$) (Table 5).

The sample size calculation was done based on the results of this study. The overall nonunion rate for displaced scaphoid fractures treated surgically was around 2% and the nonunion rate for displaced scaphoid fractures treated in a plaster cast was around 18%. This means that to set up a randomised study comparing surgery versus plaster cast treatment of displaced

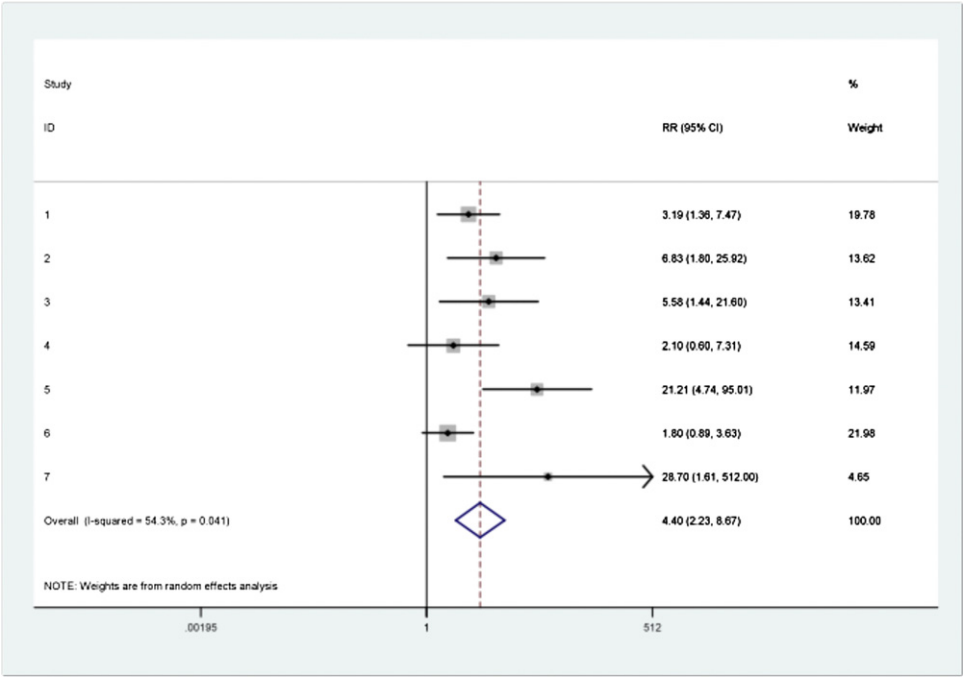

Fig. 1. Forest plot with the relative risks Heterogeneity chi-squared = 13.14 (d.f. = 6), $p = 0.041$, I-squared (variation in RR attributable to heterogeneity) = 54.3%, estimate of between-study variance tau-squared = 0.4173, test of RR = 1: $z = 4.27$, $p = 0.000$, study numbers are as per Table 1.

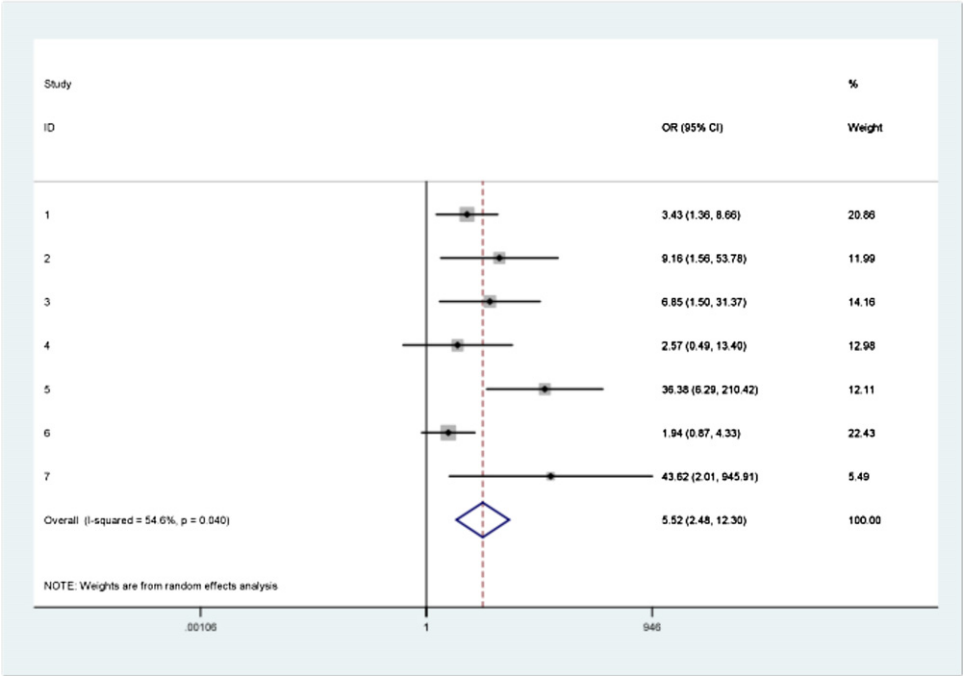

Fig. 2. Forest plot with the odds ratios. Study numbers are as per Table 1.

fractures of the waist of the scaphoid would require around 150 scaphoid fractures allowing for 10% loss to follow-up with 90% power and a type 1 error rate of 0.05. A multicentre trial is required for such a study.

Discussion

This article shows that 15% of fractures of the scaphoid are displaced with a gap or step of more than 1 mm between fractured fragments. This is similar to previous studies where displacement was seen in 18–28% of all scaphoid fractures.[2,3] However, difficulty with visualisation of scaphoid fractures on radiographs is recognised.[23,24]

Displaced scaphoid fractures can be treated in a plaster cast accepting the displacement with a higher risk of nonunion. Undisplaced fractures of the scaphoid have around a 10% rate of nonunion with treatment in a below-elbow plaster cast.[2] A large prospective study showed a 14% risk of nonunion in 63 displaced fractures of the waist of the scaphoid treated in a below-elbow plaster with the thumb left free.[2] However, the rates have been

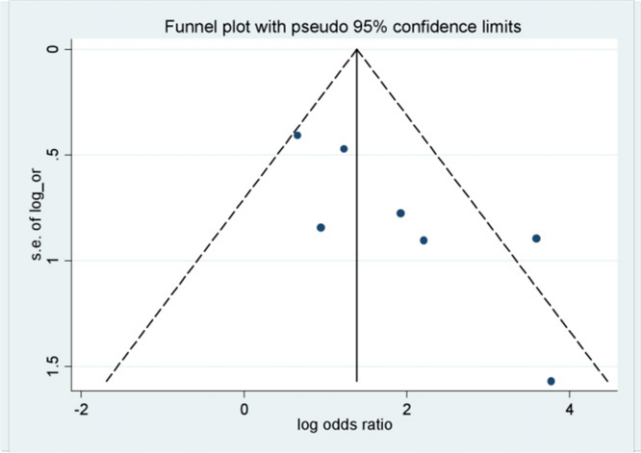

Fig. 3. Funnel plot (study by Bhat et al. lies outside the triangle due to zero cell as all undisplaced fractures healed).

shown to be higher in other studies.[6,7] Our study has shown that there is a four times higher risk of nonunion with a displaced fracture than with an undisplaced fracture if treated in a plaster cast.

Surgery reduces the risk of nonunion in displaced fractures of the waist of the scaphoid. There is an approximately 17 times greater likelihood of a nonunion with a treatment of displaced fracture of the waist of the scaphoid in a plaster cast than after surgery. This should be explained to the patient when obtaining informed consent on the merits of operative versus non-operative treatment of displaced scaphoid fractures.

There are limitations of this study. Some of the studies available for this meta-analysis are more than 30 years old. The definition of the term 'displaced' is not standardised in these studies, and the radiographic appearance of displacement of more than 1 mm depends on the position of the wrist when the radiographs were taken and on the age of the fracture. The authors of the studies were not contacted during the study, and the published data were used for the meta-analysis. The lack of randomised controlled trials meant that consecutive studies had to be used for the meta-analysis. Despite the clinical importance of controlled trials comparing different treatment options for the management of scaphoid fractures, very few studies met the criteria for this analysis. Although the included studies compared the risk of nonunion between displaced and undisplaced scaphoid fractures with cast immobilisation, different types of casts were used in these studies for different durations.

Many questions remain unanswered. Which displaced fractures will heal? How well do we reduce the deformity of the scaphoid when we fix it? Does internal fixation reduce the risk of malunion? What happens in the long term after scaphoid malunion? Future studies could also investigate whether immobilisation periods required for displaced fractures can be shortened with internal fixation?

Displaced fractures of the scaphoid have a four times higher risk of nonunion than undisplaced fractures when treated in a plaster cast. The risk is significantly lower after surgical fixation of displaced fractures of the scaphoid.

Table 4
Demographic data for surgical group.

Study	Total patients	Sex		Mean age (years)
		Male	Female	
Trumble et al.[16]	19+16 (35)	14	5	28
	Two operative groups	11	5	30
Rettig et al.[17]	14	12	2	25
Shih et al.[18]	15	13	2	29
Chao-Yu Chen[19]	11	9	2	32
Martinache and Mathoulinb[20]	37	29	8	34
Slade and Gillon[21]	67	NA	NA	24

NA: not available.

Table 5
Odds ratio of nonunion for plaster versus surgical treatment.

	Union	Nonunion	Total
Surgery	155	2	157
Plaster	170	37	207
Total	325	39	364

Odds ratio: 16.8 (95% CI: 3, 3.8–75.2), p value: 0.001.

Conflict of interest

No disclosure about any financial or personal relationships with other people or organisations that could inappropriately influence (bias) this work

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