



Original article

Considerations to improve the safety of cervical spine manual therapy

Nathan Hutting^{a,b,*}, Roger Kerry^{c,d}, Michel W. Coppieters^{e,f,g},
Gwendolijne G.M. Scholten-Peeters^f

^a Het Centrum, Centre for Physiotherapy & Manual Therapy, Rijen, The Netherlands

^b HAN University of Applied Sciences, Department of Occupation & Health, Nijmegen, The Netherlands

^c Division of Physiotherapy and Rehabilitation Sciences, University of Nottingham, Nottingham, United Kingdom

^d Department of Philosophy, University of Nottingham, Nottingham, United Kingdom

^e Menzies Health Institute Queensland, School of Allied Health Sciences, Faculty of Health, Griffith University, Gold Coast, Australia

^f Faculty of Behavioural and Movement Sciences, Vrije Universiteit Amsterdam, Amsterdam Movement Sciences, The Netherlands

^g Department of Physiotherapy, School of Health and Rehabilitation Sciences, The University of Queensland, Brisbane, Australia



ARTICLE INFO

Keywords:

Clinical reasoning
Risk factors
Serious adverse events
Cervical spine
Manual therapy
Complications

ABSTRACT

Manipulation and mobilisation of the cervical spine are well established interventions in the management of patients with headache and/or neck pain. However, their benefits are accompanied by potential, yet rare risks in terms of serious adverse events, including neurovascular insult to the brain. A recent international framework for risk assessment and management offers directions in the mitigation of this risk by facilitating sound clinical reasoning. The aim of this article is to critically reflect on and summarize the current knowledge about cervical spine manual therapy and to provide guidance for clinical reasoning for cervical spine manual therapy.

1. Introduction

In 2014, the IFOMPT 'International Framework for Examination of the Cervical Region for Potential of Cervical Arterial Dysfunction' was published (Rushton et al., 2014). The Framework aimed to guide clinical reasoning for assessment of the cervical spine region for potential cervical arterial dysfunction, prior to planning manual therapy intervention (Rushton et al., 2014). To this end, the Framework considers both ischaemic and non-ischaemic neurovascular presentations to identify possible risks (prior to any overt symptoms and signs of cervical arterial dysfunction) in a patient presenting for cervical management (Rushton et al., 2014). The Framework provides important information for clinicians to (re)consider before applying manual therapy interventions (Scholten-Peeters et al., 2014). Nevertheless, discussion continues about some items in the Framework, e.g. the relation between serious adverse events and manipulation, potential risk factors for vascular pathologies, complications after manipulation, and the usefulness of physical examination (Kerry et al., 2014; Scholten-Peeters et al., 2014).

The aim of this article is to critically reflect on and summarize the current knowledge about cervical spine manual therapy and to provide guidance for clinical reasoning in cervical spine manual therapy.

1.1. Benefits of treatment

A Cochrane review assessed the effectiveness of manipulation and mobilisation for neck pain versus an inactive control or another active treatment (Gross et al., 2015). The authors concluded that, although there was evidence for the use of thoracic manipulation versus control, the evidence for cervical manipulation and mobilisation versus control was limited. The authors found that manipulation versus mobilisation presented similar results at immediate/short/intermediate-term follow-up. However, multiple cervical manipulation sessions provided better pain relief and functional improvement than medication (analgesics and non-steroidal anti-inflammatory drugs) at immediate/intermediate/long-term follow-up (Gross et al., 2015). Since manipulation carries a risk of rare but serious adverse events, the authors recommended additional high-quality research focusing on mobilisation, and comparing mobilisation or manipulation versus other treatment options, to guide clinicians in their optimal treatment choices (Gross et al., 2015). Recently, a best evidence synthesis concerning the effectiveness of manual therapies, in the management of patients with whiplash-associated disorders or neck pain was performed (Wong et al., 2016). The authors concluded that mobilisation, manipulation, and clinical massage are effective interventions for the management of neck

* Corresponding author. HAN University of Applied Sciences, P.O. Box 6960, 6503 GL, Nijmegen, The Netherlands.
E-mail address: nathan.hutting@han.nl (N. Hutting).

pain. Another review, investigating the effectiveness of multimodal care in the management of patients with whiplash-associated disorders or neck pain found that multimodal care that includes manual therapy, education, and exercise may benefit patients with grades I and II whiplash-associated disorders and neck pain (Sutton et al., 2016).

1.2. Indications for cervical spine manipulation

Careful consideration of the indication for cervical spine manipulation is necessary, as a substantial percentage of manipulations may be performed for inappropriate conditions (Puentedura et al., 2012). Conditions indicated for the use of cervical spine manipulation include mechanical neck pain, stiffness, cervicogenic headache and cervical radiculopathy (Coulter et al., 1996). Typical clinical presentations that would suggest an indication for manipulation include: a primary complaint of neck pain; a problem that is mechanical in nature and fits with a biomechanical pattern that is regular and recognisable; limited range of motion (direction specific); pain that has clear mechanical aggravating and easing positions or movements; and local provocation tests that produce recognisable symptoms (Dewitte et al., 2014).

1.3. Risk of cervical spine manipulation

After cervical spine manipulation, the estimated incidence of serious adverse events ranges from 1 per 50,000 to 1 per 5.85 million manipulations (Haldeman et al., 2001; Magarey et al., 2004; Rivett et al., 2005). Serious adverse events are however thought to be under-reported (Kerry et al., 2008b). The best design to examine the association between manipulation and serious adverse events is a case-control study (Cassidy et al., 2012). The most recent case-control and case-crossover studies found a similar association between chiropractic care compared to care delivered by primary care physicians and vertebral-basilar strokes and carotid artery strokes (Cassidy et al., 2008, 2017). Therefore, the association between manipulation (more specifically, cervical spine manipulation) and craniocervical artery dissection (Cassidy et al., 2008, 2017; Rothwell et al., 2001; Schievink, 2001) may be confounded by indication, caused by patients with pre-existing vascular pathologies who are seeking care (Biller et al., 2014; Cassidy et al., 2008, 2017, 2012; Church et al., 2016; Kosloff et al., 2015; Murphy et al., 2016).

Craniocervical artery dissection is most prevalent in the upper cervical spine (Biller et al., 2014) and an important cause of stroke in young people, with a prevalence of up to 20% of strokes in this population (Blum and Yaghi, 2015; Debette and Leys, 2009; Dziewas et al., 2003; Goeggel Simonetti et al., 2015; Schievink, 2001). The cause of craniocervical artery dissection is largely unexplained and should be further investigated; however, most likely it involves an underlying abnormality of the vessel wall as well as triggering factors, such as minor head or neck trauma or infection (Brandt et al., 2001; Debette, 2014; Guillon et al., 2003; Robertson and Koyfman, 2016).

Each estimate of increased risk of craniocervical artery dissection should be weighed against the probability of craniocervical artery dissection that each person has (Scholten-Peeters et al., 2014). The annual incidence of a spontaneous carotid arterial dissection is 2.3–3.0 per 100,000 people and the incidence of a vertebral arterial dissection is 1.0–1.5 per 100,000 people (Debette and Leys, 2009; Dziewas et al., 2003; Schievink, 2001). A mechanical trigger (e.g. an insignificant trauma to the neck or cervical manipulation) may then trigger craniocervical artery dissection (Debette and Leys, 2009; Dittrich et al., 2007; Engelter et al., 2013; Robertson and Koyfman, 2016; Thomas et al., 2011). However, it is also possible that these people could have a spontaneous craniocervical artery dissection anyway (Scholten-Peeters et al., 2014). However, we cannot rule out the possibility that cervical spine manipulation itself, in extremely rare cases, may cause a serious adverse event (Eriksen et al., 2011).

In the IFOMPT Framework the acronym ‘CAD’ is used for the term

Cervical Arterial Dysfunction which refers to a broad range of internal carotid or vertebral arterial pathologies, including atherosclerosis, thrombosis, aneurysmal, vascular anomalies, and dissection (Rushton et al., 2014). However, this acronym might lead to confusion because ‘CAD’ is used in the non-manual therapy literature to refer to either coronary artery disease, carotid artery dissection, or (cranio)cervical arterial dissection (Kerry et al., 2014). We propose to change this acronym into CADF (*Cervical Arterial DysFunction*) to make the distinction more clearly with cervical arterial dissection (CAD).

1.4. Risk factors

Especially younger people (< 45 years) seem to have an increased risk to develop a craniocervical artery dissection, as opposed to older people with multiple cardiovascular risk factors for atherosclerosis (Cassidy et al., 2008, 2017; Goeggel Simonetti et al., 2015; Kranenburg et al., 2017; Rothwell et al., 2001; Rubinstein et al., 2005; Schievink, 2001; Traenka et al., 2017). A review of 134 case reports of serious adverse events after cervical spine manipulation showed that the mean age of these people was 44 (range 23–86) years, and only 26.1% were older than 50 years (Puentedura et al., 2012). In that review, vascular pathologies as a pre-existing condition accounted for only 13.3% the people having a serious adverse event after cervical spine manipulation (Puentedura et al., 2012). Another recent review including 227 cases of adverse events after spinal manipulation/mobilisation was not able to extract a patient profile, related to the risk of adverse events after cervical spine manipulation (Kranenburg et al., 2017). Another group found that cardiovascular risk factors commonly associated with stroke were not strongly represented in the dissection group as compared to the non-dissection controls (Thomas et al., 2011). In that study there was a mean of 1.4 cardiovascular risk factors per dissection, compared with 3.2 in the non-dissection group (Thomas et al., 2011). Moreover, the odds ratios of these risk factors were smaller than 1, which means that factors such as hypertension, smoking status, and high cholesterol, may even seem to be protective for craniocervical artery dissection in younger persons (Rubinstein et al., 2005; Scholten-Peeters et al., 2014;

Table 1
Risk factors for cervical artery dissection.

Risk factor	Odds ratio (95% CI)	Reference
Recent head or neck trauma	23.51 (5.71–96.89)	Thomas et al. (2011)
Manipulative therapy	60.0 (8.7 – infinity)	Thomas et al. (2015)
	12.67 (6.31–87.70)	Thomas et al. (2011)
	5.03 (1.32–43.87)	Rothwell et al. (2001)
	6.6 (1.4–30)	Smith et al. (2003)
	3.60 (1.46–10.84)	Cassidy et al. (2008)
	5.2 (0.6 – infinity)	Thomas et al. (2015)
Migraine	1.54 (0.51–4.67)	Thomas et al. (2011)
	2.06 (1.33–3.19)	Rist et al. (2011)
	1.51 (1.15–1.99)	Metso et al. (2012)
	6.7 (1.3–38.0)	Thomas et al. (2015)
Recent infection	3.77 (1.07–13.24)	Thomas et al. (2011)
	3.5 (1.2–16.7)	Dittrich et al. (2007)
	2.5 (0.4–14.5)	Thomas et al. (2015)
Craniocervical vascular anomaly	3.0 (0.99–9.02)	Thomas et al. (2011)
	1.9 (0.3–11.6)	Thomas et al. (2015)
Hypertension	0.29 (0.11–0.79)	Thomas et al. (2011)
	0.8 (0.2–3.1)	Thomas et al. (2015)
	1.67 (1.42–2.1)	Debette et al. (2011)
Oral contraception	1.32 (0.31–5.69)	Thomas et al. (2011)
	0.3 (0.08–1.3)	Thomas et al. (2015)
Family history of stroke	0.55 (0.16–1.88)	Thomas et al. (2011)
	0.9 (0.05–14.8)	Thomas et al. (2015)
High cholesterol	0.33 (0.12–0.85)	Thomas et al. (2011)
	0.06 (0.01–0.5)	Thomas et al. (2015)
	0.55 (0.42–0.71)	Debette et al. (2011)
Current or past smoker	0.31 (0.13–0.78)	Thomas et al. (2011)
	0.4 (0.09–1.3)	Thomas et al. (2015)

CI = confidence interval.

Thomas et al., 2011). Table 1 presents an overview of the potential risk factors for which the association with craniocervical artery dissection is known. In general, there seem to be a strong association for risk factors with a genetic component, while there is only a weak association for environmental factors, except for and for trivial head or neck trauma (Debette and Leys, 2009; Rubinstein et al., 2005; Thomas et al., 2011, 2017).

General cardiovascular risk factors, with the exception of diagnosed migraine, do not appear to be important risk factors for craniocervical artery dissection, but appear to be risk factors for other vascular pathology, such as atherosclerosis (Debette and Leys, 2009; Thomas et al., 2011, 2015). However, the pathophysiology of craniocervical artery dissection is incompletely understood and should be further investigated (Debette, 2014; Robertson and Koyfman, 2016).

Atherosclerosis is an inflammatory process associated with a number of factors, including hypertension, hypercholesterolaemia, hyperlipidaemia, diabetes mellitus, infections, and smoking (Taylor and Kerry, 2010). Risk factors for atherosclerosis are often present in older people and thrombotic stroke is typically a disease of the elderly (Debette and Leys, 2009). Therefore, in older people, it is important to address all these atherosclerosis related factors in the patient interview, as their presence is a risk factor for vascular pathology and might be a contraindication for manipulation.

1.5. Contraindications

In a review of 134 case reports, the most common pre-existing serious pathologies for serious adverse events were bony pathologies (70%), including severe osteoporosis, spondylosis and rheumatoid arthritis (Puentedura et al., 2012). These conditions are clear contraindications to cervical spine manipulation, and some are identifiable through a detailed patient interview and clinical examination (Puentedura et al., 2012).

Table 2 presents an overview of contraindications and precautions for cervical spine manual therapy. Cervical spine manual therapy should not be performed when contraindications or unexplained red flags are present, as these might be associated with serious pathologies and, thus, contraindicated for manual therapy (Refshauge et al., 2002).

1.6. Clinical reasoning

Prior to cervical spine manual therapy, a risk-benefit analysis should be performed (Rushton et al., 2014) in which the potential risks for

vascular pathologies and (vascular) complications after manipulation should be weighed against the potential benefits. This risk should be estimated for each patient, based on all current factors surrounding the particular situation at that particular time (Kerry et al., 2008a). In their clinical reasoning, manual therapists must rely on information based on the patient interview and physical examination with regard to clinical signs and symptoms and available risk factors for the different diseases/disorders and interpret this information carefully. There are three important steps in the clinical reasoning process: 1) identifying a possible vasculogenic contribution or other serious pathology; 2) determining whether there is an indication or contraindication for mobilisation or manipulation; and 3) assessing the presence of any potential risk factors associated with potential serious adverse events which are reported to occur after cervical spine mobilisation and/or manipulation. Supplementary Material 1 presents a flowchart that emphasises these important steps in the clinical reasoning process.

1.7. The patient interview

The patient interview is essential to identify potential risk factors, red flags and contraindications, and also to create initial hypotheses to be further investigated in the clinical examination (Rushton et al., 2014). With regard to the prevention of serious adverse events, identifying a possible vasculogenic contribution to the complaints is important. Severe, unusual headache or neck pain are often the first symptoms of an underlying craniocervical artery dissection (Debette and Leys, 2009; Taylor and Kerry, 2010). In patients older than 60 years, pain and mechanical triggers might be missing because cervical pain is not a hallmark of craniocervical artery dissection in patients older than 60 years (Traenka et al., 2017). Interpreting data from the patient interview and defining the main hypothesis is essential for an effective physical examination (Petty, 2011; Rushton and Lindsay, 2010).

1.8. Physical examination

Tests for upper cervical spine instability or premanipulative vertebrobasilar insufficiency tests do not seem to be of important value in premanipulative screening, due to low diagnostic accuracy and low pretest probability (Hutting et al., 2013a, 2013b). Especially the low sensitivity of these tests can result in a high rate of patients being wrongly classified as 'low-risk patients' (false negatives) for serious adverse events (Hutting et al., 2013a, 2013b). However, given the high

Table 2
Contraindications and precautions to perform cervical spine manual therapy (Puentedura et al., 2012; Rushton et al., 2014).

Contraindications	Precautions
• (Acute) fracture • Relevant recent trauma • Dislocation • Ligamentous rupture • Instability • Active cancer • Acute myelopathy • Spinal cord damage • Upper motor neuron lesions • Multi-level nerve root pathology • Worsening neurological function • Recent surgery • Acute soft tissue injury • Unremitting, severe, non-mechanical pain • Unremitting night pain • Vertebral/carotid artery abnormalities • Vertebrobasilar insufficiency	• Inflammatory disease • Rheumatoid arthritis • Ankylosing spondylitis • History of cancer • Long-term steroid use • Osteoporosis • Systemically unwell • Hypermobility syndromes • Connective tissue disease • A first sudden episode before age 18 or after age 55 • Cervical anomalies • Local infection • Throat infection • Recent manipulation by another health professional • Vascular disease • Blood clotting disorders/alterations in blood properties • Anticoagulant therapy • Absence of a plausible mechanical explanation for the patient's symptoms • Immediately post-partum

specificity of the upper cervical spine instability tests and pre-manipulative vertebrobasilar insufficiency tests these tests can be valuable in detecting upper cervical spine instability or vertebrobasilar insufficiency (Hutting et al., 2013a, 2013b), which are both contraindications for cervical spine manual therapy. In case the patient interview indicates an expected vascular contribution or upper cervical spine instability, premanipulative vertebrobasilar insufficiency testing and upper cervical spine instability testing seems not to be prudent and might even be harmful for the patient.

As general cardiovascular risk factors generally do not appear to be associated with craniocervical artery dissection in younger persons, routine assessment of these cardiovascular risk factors in the physical examination (e.g. measuring blood pressure) in younger people may not be particularly useful for manual therapists when aiming to determine the risks of serious adverse events in these patients (Thomas et al., 2011, 2017). In older patients, measuring blood pressure may be considered, since hypertension is a recognised risk factor for both stroke and cardiovascular disease (Taylor and Kerry, 2013; Traenka et al., 2017). However, the diagnostic validity and reliability of blood pressure measurement (in addition to the patient interview) with regard to assessing vascular risk factors in manual therapy practice is unknown and needs further investigation. Patients with hypertension that has not been previously identified should be advised to discuss its implications with their primary care provider (Rushton et al., 2014).

1.9. Applying cervical spine manual therapy

If there is an indication for cervical mobilisation or manipulation, the appropriate technique and the intensity of the technique should be determined. There is no clear evidence that any one technique has a higher risk compared to the other techniques. However, the basic principle underlying all the techniques should be that minimal force is applied to any structure in the cervical spine, i.e. low amplitude, short lever thrusts (Rushton et al., 2014). Moreover, cervical manipulation should not be performed at the end of range of cervical movement, particularly extension and rotation (Rushton et al., 2014). Since isolated cervical spine manipulation and mobilisation produce similar patient related outcomes, mobilisation can be used as an alternative for manipulation. Unfortunately, knowledge is lacking on possible serious adverse events after mobilisation and specific risk factors for complications after mobilisation, which can also place stress on blood vessels and connective tissue. The contraindications discussed in the IFOMPT Framework also apply in case of mobilisation or exercises. However, it is possible that contraindications for manipulation, mobilisation or exercises may vary and further research in this area is recommended (Puentedura et al., 2012).

2. Conclusions

Although there seems to be no causality between cervical spine manipulation and serious adverse events (in particular, craniocervical artery dissection) it is important that manual therapists try to prevent every potential serious adverse event caused by vascular or other pathologies. Therefore, thorough patient interviewing, clinical assessment, interpretation and analysis are important skills needed to determine an indication for manual therapy. In case there is a possible vasculogenic contribution, cervical spine manual therapy is contraindicated. Also, in the event of other contraindications or risk factors for possible serious adverse events, cervical spine manipulation or mobilisation should not be performed. The various topics discussed in this professional issue can support manual therapists in their clinical reasoning process to improve the safety of manual therapy.

Declarations

This article presents the authors' personal opinions.

Conflicts of interest

NH is a member of the Board of the Dutch Association for Manual Therapy (NVMT) and the member organisation delegate for the Netherlands in the International Federation of Orthopaedic Manipulative Physical Therapists (IFOMPT). The authors declare that they have no conflicts of interest.

Funding

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Appendix A. Supplementary data

Supplementary data related to this article can be found at <http://dx.doi.org/10.1016/j.msksp.2017.11.003>.

References

- Billor, J., Sacco, R.L., Albuquerque, F.C., Demaerschalk, B.M., Fayad, P., Long, P.H., Noorollah, L.D., Panagos, P.D., Schievink, W.I., Schwartz, N.E., Shuaib, A., Thaler, D.E., Tirschwell, D.L., 2014. American Heart Association Stroke C. Cervical arterial dissections and association with cervical manipulative therapy: a statement for healthcare professionals from the American heart association/American stroke association. *Stroke* 45 (10), 3155–3174.
- Blum, C.A., Yaghi, S., 2015. Cervical artery dissection: a review of the epidemiology, pathophysiology, treatment, and outcome. *Arch. Neurosci.* 2 (4).
- Brandt, T., Orberk, E., Weber, R., Werner, I., Busse, O., Muller, B.T., Wigger, F., Grau, A., Grond-Ginsbach, C., Hauser, L., 2001. Pathogenesis of cervical artery dissections: association with connective tissue abnormalities. *Neurology* 57 (1), 24–30.
- Cassidy, J.D., Boyle, E., Cote, P., He, Y., Hogg-Johnson, S., Silver, F.L., Bondy, S.J., 2008. Risk of vertebrobasilar stroke and chiropractic care: results of a population-based case-control and case-crossover study. *Spine* 33 (4 Suppl. 1), S176–S183 (Phila Pa 1976).
- Cassidy, J.D., Boyle, E., Cote, P., Hogg-Johnson, S., Bondy, S.J., Haldeman, S., 2017. Risk of carotid stroke after chiropractic care: a population-based case-crossover study. *J. Stroke Cerebrovasc. Dis.* 26 (4), 842–850.
- Cassidy, J.D., Bronfort, G., Hartvigsen, J., 2012. Should we abandon cervical spine manipulation for mechanical neck pain? *No. BMJ* 344, e3680.
- Church, E.W., Sieg, E.P., Zlatimo, O., Hussain, N.S., Glantz, M., Harbaugh, R.E., 2016. Systematic review and meta-analysis of chiropractic care and cervical artery dissection: No evidence for causation. *Cureus* 8 (2), e498.
- Coulter, I., Hurwitz, E., Adams, A., Meeker, W., Hansen, D., Mootz, R., 1996. The Appropriateness of Spinal Manipulation and Mobilization of the Cervical Spine. Rand Publishing, Santa Monica, CA.
- Debette, S., 2014. Pathophysiology and risk factors of cervical artery dissection: what have we learnt from large hospital-based cohorts? *Curr. Opin. Neurol.* 27 (1), 20–28.
- Debette, S., Leys, D., 2009. Cervical-artery dissections: predisposing factors, diagnosis, and outcome. *Lancet Neurol.* 8 (7), 668–678.
- Debette, S., Metso, T., Pezzini, A., Abboud, S., Metso, A., Leys, D., Bersano, A., Louillet, F., Caso, V., Lamy, C., Medeiros, E., Samson, Y., Grond-Ginsbach, C., Engelter, S.T., Thijs, V., Beretta, S., Bejot, Y., Sessa, M., Lorenza Muesan, M., Amouyel, P., Castellano, M., Arveiler, D., Tatlisumak, T., Dallongeville, J., Cervical Artery D, Ischemic Stroke Patients G, 2011. Association of vascular risk factors with cervical artery dissection and ischemic stroke in young adults. *Circulation* 123 (14), 1537–1544.
- Dewitte, V., Beernaert, A., Vanthillo, B., Barbe, T., Danneels, L., Cagnie, B., 2014. Articular dysfunction patterns in patients with mechanical neck pain: a clinical algorithm to guide specific mobilization and manipulation techniques. *Man. Ther.* 19 (1), 2–9.
- Dittrich, R., Rohsbad, D., Heidebreder, A., Heuschmann, P., Nassenstein, I., Bachmann, R., Ringelstein, E.B., Kühlenbaumer, G., Nabavi, D.G., 2007. Mild mechanical traumas are possible risk factors for cervical artery dissection. *Cerebrovasc. Dis.* 23 (4), 275–281.
- Dziwias, R., Konrad, C., Dräger, B., Evers, S., Besselmann, M., Ludemann, P., Kühlenbaumer, G., Stogbauer, F., Ringelstein, E.B., 2003. Cervical artery dissection—clinical features, risk factors, therapy and outcome in 126 patients. *J. Neurol.* 250 (10), 1179–1184.
- Engelter, S.T., Grond-Ginsbach, C., Metso, T.M., Metso, A.J., Kloss, M., Debette, S., Leys, D., Grau, A., Dallongeville, J., Bodenandt, M., Samson, Y., Caso, V., Pezzini, A., Bonati, L.H., Thijs, V., Gensicke, H., Martin, J.J., Bersano, A., Touze, E., Tatlisumak, T., Lyrer, P.A., Brandt, T., 2013. Cervical Artery D, Ischemic Stroke Patients Study G. Cervical artery dissection: trauma and other potential mechanical trigger events. *Neurology* 80 (21), 1950–1957.
- Eriksen, K., Rochester, R.P., Hurwitz, E.L., 2011. Symptomatic reactions, clinical outcomes and patient satisfaction associated with upper cervical chiropractic care: a prospective, multicenter, cohort study. *BMC Musculoskelet. Disord.* 12, 219.
- Goeggel Simonetti, B., Mono, M.L., Huynh-Do, U., Michel, P., Odier, C., Sztajzel, R., Lyrer, P., Engelter, S.T., Bonati, L., Gensicke, H., Traenka, C., Tettlenborn, B., Weder, B.,

- Fischer, U., Galimanis, A., Jung, S., Luedi, R., De Marchis, G.M., Weck, A., Cereda, C.W., Baumgartner, R., Bassetti, C.L., Mattle, H.P., Nedeltchev, K., Arnold, M., 2015. Risk factors, aetiology and outcome of ischaemic stroke in young adults: the Swiss Young Stroke Study (SYSS). *J. Neurol.* 262 (9), 2025–2032.
- Gross, A., Langevin, P., Burnie, S.J., Bedard-Brochu, M.S., Empey, B., Dugas, E., Faber-Dobrescu, M., Andres, C., Graham, N., Goldsmith, C.H., Bronfort, G., Hoving, J.L., LeBlanc, F., 2015. Manipulation and mobilisation for neck pain contrasted against an inactive control or another active treatment. *Cochrane Database Syst. Rev.* 9, CD004249.
- Guillon, B., Berthet, K., Benslamia, L., Bertrand, M., Bousser, M.G., Tzourio, C., 2003. Infection and the risk of spontaneous cervical artery dissection: a case-control study. *Stroke* 34 (7), e79–81.
- Haldeman, S., Carey, P., Townsend, M., Papadopoulos, C., 2001. Arterial dissections following cervical manipulation: the chiropractic experience. *CMAJ* 165 (7), 905–906.
- Hutting, N., Scholten-Peeters, G.G., Vijverman, V., Keesenberg, M.D., Verhagen, A.P., 2013a. Diagnostic accuracy of upper cervical spine instability tests: a systematic review. *Phys. Ther.* 93 (12), 1686–1695.
- Hutting, N., Verhagen, A.P., Vijverman, V., Keesenberg, M.D., Dixon, G., Scholten-Peeters, G.G., 2013b. Diagnostic accuracy of premanipulative vertebrobasilar insufficiency tests: a systematic review. *Man. Ther.* 18 (3), 177–182.
- Kerry, R., Rushton, A., Flynn, T., Hing, W., Carlesso, L., Rivett, D., 2014. Response to - risk reduction of serious complications from manual therapy: are we reducing the risk? *Man. Ther.* 19 (3), e3–4.
- Kerry, R., Taylor, A.J., Mitchell, J., McCarthy, C., 2008a. Cervical arterial dysfunction and manual therapy: a critical literature review to inform professional practice. *Man. Ther.* 13 (4), 278–288.
- Kerry, R., Taylor, A.J., Mitchell, J., McCarthy, C., Brew, J., 2008b. Manual therapy and cervical arterial dysfunction, directions for the future: a clinical perspective. *J. Man. Manip. Ther.* 16 (1), 39–48.
- Kosloff, T.M., Elton, D., Tao, J., Bannister, W.M., 2015. Chiropractic care and the risk of vertebrobasilar stroke: results of a case-control study in U.S. commercial and Medicare Advantage populations. *Chiropr. Man. Ther.* 23, 19.
- Kranenburg, H.A., Schmitt, M.A., Puente-dura, E.J., Luijckx, G.J., van der Schans, C.P., 2017. Adverse events associated with the use of cervical spine manipulation or mobilization and patient characteristics: a systematic review. *Musculoskelet. Sci. Pract.* 28, 32–38.
- Magarey, M.E., Rebbeck, T., Coughlan, B., Grimmer, K., Rivett, D.A., Refshauge, K., 2004. Pre-manipulative testing of the cervical spine review, revision and new clinical guidelines. *Man. Ther.* 9 (2), 95–108.
- Metso, T.M., Tatlisumak, T., DeBette, S., Dallongeville, J., Engelter, S.T., Lyrer, P.A., Thijs, V., Bersano, A., Abboud, S., Leys, D., Grond-Ginsbach, C., Kloss, M., Touze, E., Pezzini, A., Metso, A.J., Group C, 2012. Migraine in cervical artery dissection and ischemic stroke patients. *Neurology* 78 (16), 1221–1228.
- Murphy, D.R., Schneider, M.J., Perle, S.M., Bise, C.G., Timko, M., Haas, M., 2016. Does case misclassification threaten the validity of studies investigating the relationship between neck manipulation and vertebral artery dissection stroke? *No. Chiropr. Man. Ther.* 24, 43.
- Petty, N., 2011. *Neuromusculoskeletal Examination and Assessment: a handbook for therapists (physiotherapy essentials)*, fourth ed. Churchill Livingstone, Elsevier, Edinburgh.
- Puente-dura, E.J., March, J., Anders, J., Perez, A., Landers, M.R., Wallmann, H.W., Cleland, J.A., 2012. Safety of cervical spine manipulation: are adverse events preventable and are manipulations being performed appropriately? A review of 134 case reports. *J. Man. Manip. Ther.* 20 (2), 66–74.
- Refshauge, K.M., Parry, S., Shirley, D., Larsen, D., Rivett, D.A., Boland, R., 2002. Professional responsibility in relation to cervical spine manipulation. *Aust. J. Physiother.* 48 (3), 171–179 discussion 80–85.
- Rist, P.M., Diener, H.C., Kurth, T., Schurks, M., 2011. Migraine, migraine aura, and cervical artery dissection: a systematic review and meta-analysis. *Cephalalgia* 31 (8), 886–896.
- Rivett, D.A., Thomas, L., Bolton, P., 2005. Pre-manipulative testing: where do we go from here? *N. Z. J. Physiother.* 33 (3), 78–84.
- Robertson, J.J., Koyfman, A., 2016. Cervical artery dissections: a review. *J. Emerg. Med.* 51 (5), 508–518.
- Rothwell, D.M., Bondy, S.J., Williams, J.I., 2001. Chiropractic manipulation and stroke: a population-based case-control study. *Stroke* 32 (5), 1054–1060.
- Rubinstein, S.M., Peerdeman, S.M., van Tulder, M.W., Riphagen, I., Haldeman, S., 2005. A systematic review of the risk factors for cervical artery dissection. *Stroke* 36 (7), 1575–1580.
- Rushton, A., Lindsay, G., 2010. Defining the construct of masters level clinical practice in manipulative physiotherapy. *Man. Ther.* 15 (1), 93–99.
- Rushton, A., Rivett, D., Carlesso, L., Flynn, T., Hing, W., Kerry, R., 2014. International framework for examination of the cervical region for potential of Cervical Arterial Dysfunction prior to Orthopaedic Manual Therapy intervention. *Man. Ther.* 19 (3), 222–228.
- Schievink, W.I., 2001. Spontaneous dissection of the carotid and vertebral arteries. *N. Engl. J. Med.* 344 (12), 898–906.
- Scholten-Peeters, G.G., van Trijffel, E., Hutting, N., Castien, R.F., Rooker, S., Verhagen, A.P., 2014. Risk reduction of serious complications from manual therapy: are we reducing the risk?: correspondence to: international framework for examination of the cervical region for potential of cervical arterial dysfunction prior to orthopaedic manual therapy intervention by. *Man. Ther.* 19 (6), e5–6.
- Smith, W.S., Johnston, S.C., Skalabrin, E.J., Weaver, M., Azari, P., Albers, G.W., Gress, D.R., 2003. Spinal manipulative therapy is an independent risk factor for vertebral artery dissection. *Neurology* 60 (9), 1424–1428.
- Sutton, D.A., Cote, P., Wong, J.J., Varatharajan, S., Randhawa, K.A., Yu, H., Southerst, D., Shearer, H.M., van der Velde, G.M., Nordin, M.C., Carroll, L.J., Mior, S.A., Taylor-Vaisey, A.L., Stupar, M., 2016. Is multimodal care effective for the management of patients with whiplash-associated disorders or neck pain and associated disorders? A systematic review by the Ontario Protocol for Traffic Injury Management (OPTIMA) collaboration. *Spine J.* 16 (12), 1541–1565.
- Taylor, A., Kerry, R., 2010. A 'system based' approach to risk assessment of the cervical spine prior to manual therapy. *Int. J. Osteopath. Med.* 13 (3), 85–93.
- Taylor, A.J., Kerry, R., 2013. Vascular profiling: should manual therapists take blood pressure? *Man. Ther.* 18 (4), 351–353.
- Thomas, L.C., Makaroff, A.P., Oldmeadow, C., Attia, J.R., Levi, C.R., 2017. Seasonal variation in cervical artery dissection in the Hunter New England region, New South Wales, Australia: a retrospective cohort study. *Musculoskelet. Sci. Pract.* 27, 106–111.
- Thomas, L.C., Rivett, D.A., Attia, J.R., Levi, C., 2015. Risk factors and clinical presentation of cervical arterial dissection: preliminary results of a prospective case-control study. *J. Orthop. Sports Phys. Ther.* 45 (7), 503–511.
- Thomas, L.C., Rivett, D.A., Attia, J.R., Parsons, M., Levi, C., 2011. Risk factors and clinical features of craniocervical arterial dissection. *Man. Ther.* 16 (4), 351–356.
- Traenka, C., Dougoud, D., Simonetti, B.G., Metso, T.M., DeBette, S., Pezzini, A., Kloss, M., Grond-Ginsbach, C., Majersik, J.J., Worrall, B.B., Leys, D., Baumgartner, R., Caso, V., Bejot, Y., Compter, A., Reiner, P., Thijs, V., Southerland, A.M., Bersano, A., Brandt, T., Gensicke, H., Touze, E., Martin, J.J., Chabiat, H., Tatlisumak, T., Lyrer, P., Arnold, M., Engelter, S.T., Group, C.A.-P.S., 2017 Apr 4. Cervical artery dissection in patients > / = 60 years: often painless, few mechanical triggers. *Neurology* 88 (14), 1313–1320.
- Wong, J.J., Shearer, H.M., Mior, S., Jacobs, C., Cote, P., Randhawa, K., Yu, H., Southerst, D., Varatharajan, S., Sutton, D., van der Velde, G., Carroll, L.J., Ameis, A., Ammendolia, C., Brison, R., Nordin, M., Stupar, M., Taylor-Vaisey, A., 2016. Are manual therapies, passive physical modalities, or acupuncture effective for the management of patients with whiplash-associated disorders or neck pain and associated disorders? An update of the Bone and Joint Decade Task Force on Neck Pain and its Associated Disorders by the OPTIMA collaboration. *Spine J.* 16 (12), 1598–1630.