

Radiophobia: 7 Reasons Why Radiography Used in Spine and Posture Rehabilitation Should Not Be Feared or Avoided

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Abstract

Evidence-based contemporary spinal rehabilitation often requires radiography. Use of radiography (X-rays or computed tomography scans) should not be feared, avoided, or have their exposures lessened to decrease patient dose possibly jeopardizing image quality. This is because all fears of radiation exposures from medical diagnostic imaging are based on complete fabrication of health risks based on an outdated, invalid linear model that has simply been propagated for decades. We present 7 main arguments for continued use of radiography for routine use in spinal rehabilitation: (1) the linear no-threshold model for radiation risk estimates is invalid for low-dose exposures; (2) low-dose radiation enhances health via the body's adaptive response mechanisms (ie, radiation hormesis); (3) an X-ray with low-dose radiation only induces 1 one-millionth the amount of cellular damage as compared to breathing air for a day; (4) radiography is below inescapable natural annual background radiation levels; (5) radiophobia stems from unwarranted fears and false beliefs; (6) radiography use leads to better patient outcomes; (7) the risk to benefit ratio is always beneficial for routine radiography. Radiography is a safe imaging method for routine use in patient assessment, screening, diagnosis, and biomechanical analysis and for monitoring treatment progress in daily clinical practice.

Keywords

radiophobia, radiography, X-ray, low-dose radiation, linear no-threshold (LNT), ALARA

Introduction

The common X-ray is an essential tool for doctors and manual therapists in the treatment of musculoskeletal and neuromusculoskeletal diseases and conditions associated with poor posture and spinal deformity.¹⁻¹⁰ There has been an ever-expanding evidence base substantiating the effectiveness of nonsurgical rehabilitative methods for the treatment of posture and spinal deformities, such as forward head posture,¹¹⁻²⁰ cervical hypolordosis/kyphosis,¹⁴⁻²¹ thoracic hyperkyphosis,²²⁻²⁹ thoracic hypokyphosis,^{30,31} lumbar hypolordosis/kyphosis,³²⁻³⁷ and scoliosis.³⁸⁻⁴¹

The common radiograph is an invaluable tool that will continue to be a “go to” procedure to assess and monitor treatment effects related to improving posture with contemporary treatment approaches.¹¹⁻⁴¹ There are, however, many fears concerning the exposure of radiation (ie, radiophobia), particularly for the acquisition of diagnostic medical X-rays (including computed tomography [CT] scans).⁴²⁻⁴⁷

Radiophobia stems from decades of scientifically erroneous extrapolations from high-dose atomic bomb survivor data assumed to be linear down to a zero exposure, the so-called

“linear no-threshold” (LNT) hypothesis or model. This simple linear model has been the basis for safety standards and theoretical cancer estimates for over 60 years.^{48,49}

There are many reasons why routine radiography is not only feared but also often avoided—unnecessarily—not only by the patient but also by the doctor. We argue that radiography should not be feared and should remain a routine procedure in rehabilitative clinical practice for 7 main reasons:

1. The LNT model for radiation risk estimates is invalid for low-dose exposures.

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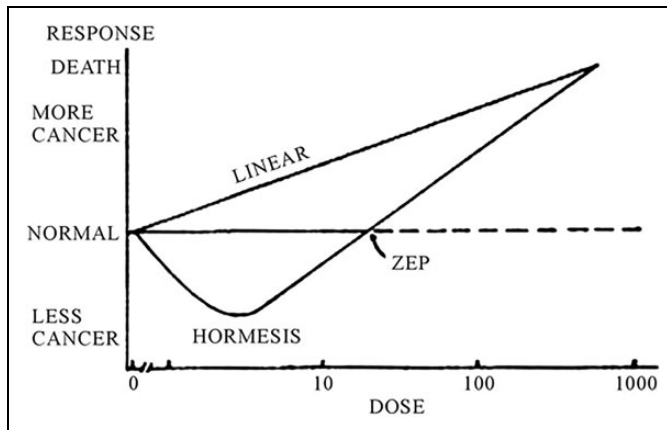


Figure 1. Linear no-threshold (LNT) model versus hormesis model of cancer incidence. The LNT model depicts linear relationship between dose rate and cancer induction; hormesis model depicts less cancers at lower doses; where at the “zero equivalent point” (ZEP), the model crosses over to mimic the LNT model at higher doses, having more cancers linearly related to dose rate.

2. Low-dose radiation enhances health via the body’s adaptive response mechanisms (ie, radiation hormesis).
3. An X-ray with low-dose radiation only induces 1 one-millionth the amount of cellular damage as compared to breathing air for a day.
4. Radiography is below inescapable natural annual background radiation levels.
5. Radiophobia stems from unwarranted fears and false beliefs.
6. Radiography use leads to better patient outcomes.
7. The risk to benefit ratio is always beneficial for routine radiography.

The purpose of this article is to discuss the rationale behind 7 main reasons why radiography as used in spinal rehabilitative medicine should not be feared or avoided due to unwarranted radiophobia by patients or their provider in daily clinical practice.

The LNT Model for Radiation Risk Estimates Is Invalid for Low-dose Exposures

The LNT model for estimating radiation risk assumes that high-dose dose–response data from the Nagasaki/Hiroshima atomic bomb survivors (in the Life Span Study) can be linearly extrapolated down to zero dose (Figure 1).⁵⁰ Therefore, this model theoretically assumes that all radiation is harmful, no matter the exposure level, even for radiography that is several orders of magnitude less than the high-dose atomic bomb data.

Essentially, atomic bomb exposure data are used to theoretically calculate supposed radiogenic cancers from the low doses from radiography (plain film or CT scans).^{42–47} The problem is, however, that no data have ever supported the LNT model for low-dose radiation exposures as used in radiography.^{48,49,51} Specifically, according to the Health Physics Society, no

Table 1. Typical Radiation Exposures of Common X-Ray and CT Imaging and Its Equivalent to Number of Days of Annual Background Radiation for US Average (3.1 mSv), Colorado (6 mSv), and Ramsar, Iran (260 mSv).

Body Region	Average Effective Dose (mSv)	Equivalent Days of Background		
		United States Average: 3.1 mSv	Colorado: 6 mSv	Ramsar, Iran: 260 mSv
Plain radiography				
Cervical (AP/Lat)	0.2	24	12	0
Thoracic (AP/Lat)	1	118	61	1
Lumbar (AP/Lat)	1.5	177	91	2
Full-spine series	2.7	318	164	4
CT imaging				
Head	2	235	122	3
Chest	8	942	487	11
Abdomen–pelvis	15	1766	913	21

Abbreviations: AP/Lat, anteroposterior/lateral; CO, Colorado; CT, computed tomography.

model is justified in the estimation of radiogenic health risks at doses less than 100 mSv (10 000 mrem).⁵² Ironically, and as discussed by Socol et al,⁵³ the International Commission on Radiological Protection (ICRP) admits that cancer deaths estimated using the LNT model for low doses (<100 mSv) are “speculative, unproven, undetectable, and ‘phantom’.”⁵⁴ Table 1 shows typical radiation exposures from common spinal imaging.

Even the most recent atomic bomb survivor data have been shown to be equally or better described by an S-shaped relationship as opposed to a linear one (LNT).⁵⁵ As Doss states, “Atomic bomb survivor data (generally regarded as the most important data for estimating health effects of radiation) no longer support the LNT model.”^{56,57}

Since conclusions made for low doses are based on data from only high doses, any proposed support for the LNT for the low-dose region results from “circular reasoning, cherry picking, faulty experimental design, and/or misleading inferences from weak statistical evidence.”⁵¹

Recent evidence surrounding the initial adoption of the LNT model has brought to light its dubious history. Calabrese has documented the historical time line of events surrounding the creation of the LNT model and its adoption by the national and international regulatory bodies.^{58–61} This new body of evidence is likened to the “last nail in the coffin” as it demonstrates flaws in the original research underpinning the LNT and unethical conduct by those involved; it lays to rest any last evidence the LNT had regarding its use in the low-dose range. In fact, there is a strong push from the scientific community for the termination of the LNT model as used in radiation protection standards for the low-dose range (ie, radiography).^{62–65}

With dismissal of the LNT model, of course its corollary the “As Low As Reasonably Achievable” (ALARA) concept as used in medical radiation education and practice collapses with it. There is demand within the scientific community to abandon the ALARA concept.^{56,57,66-68}

Low-Dose Radiation Enhances Health via the Body’s Adaptive Response Mechanisms (ie, Radiation Hormesis)

The body responds to stress (including radiation) by overcompensating for any damage caused during the exposure. This overcompensation is a redundant cascade of physiologic processes that occur on multiple physiologic levels.⁶⁹⁻⁷²

Hormesis refers to the J-shaped effect of low doses causing benefit and high doses causing harm from an exposure to an agent; “radiation hormesis” is the hormesis phenomenon applied to living things exposed to radiation (Figure 1). Low radiation doses stimulate health benefits, and high radiation doses are detrimental to health.

Similar to exercise, radiation exposure damages living cells. Exercise, a common act known to be physiologically positive and health promoting, leads the body to respond to muscle tissue damage by overcompensating and repairing muscle cells to be more fit and stronger following the exposure. Radiation exposure causes a similar physiological overcompensation response that in turn makes the exposed cells, tissues, and whole organism more robust and resistant to similar future exposures.

Several have discussed the incredible and sophisticated adaptive responses the body employs to protect itself from radiation and other toxic exposures.⁶⁹⁻⁷² There are different types of defense mechanisms, physical-static and metabolic-dynamic defenses. Physical-static defenses include barriers such as skin or the cell membrane. Metabolic-dynamic defenses include scavenging mechanisms, molecular repair mechanisms (including DNA), and removal of damaged cells such as by programmed cell death (apoptosis), as well as by other means. Another type of metabolic-dynamic protection is the “upregulation” of existing protection mechanisms (also known as “stress response”) that causes overcompensation, so that the organism is better able to withstand future similar exposures (including radiation).

These adaptive responses have been proven to occur in response to many challenges to the body, such as strength training, sunbathing, callus formation, and immunization. The body becomes healthier to the challenges that are within an envelope of exposure that is not sufficient to overwhelm it. The same holds true for radiation exposures from radiography. Löbrich et al determined that DNA double-strand breaks (DSBs) occur after humans receive CT scans; however, these DSBs were repaired between 5 and 24 hours after the scan.⁷³ Most importantly, the innate repair mechanisms repaired more than the damage that had initially occurred from the CT scans; the final DSB count was less than it was prior to the scan.

Siegel et al state, “This is evidence of a beneficial (hormetic) effect of low-dose ionizing radiation—and argues against radiogenic causation of either solid cancers or leukemias in children or adults”.^{65(p866)} For the record, a CT scan typically employs an order of magnitude greater radiation exposure than a plain X-ray (Table 1).

An X-Ray With Low-Dose Radiation Only Induces 1 One-Millionth the Amount of Cellular Damage as Compared to Breathing Air for a Day

Cellular damage occurs on a second-by-second basis by normal metabolism. In fact, it has been estimated that every cell in the body has about 10 billion reactive oxygen species (ROS) produced per day.^{71,74} Since most ROS molecules are produced from normal breathing, it has been stated “the production of oxygen-based radicals is the bane to all aerobic species.”⁷⁵ This is because ROS molecules (naturally produced byproducts during mitochondrial electron transport of aerobic respiration) act as a double-edged sword as they serve in both intracellular and extracellular signaling as well as contribute to pathological processes.⁷⁶

How many ROS molecules are produced from an X-ray? Feinendegen et al state that for an average microdose event, such as for a 100 kVp X-ray exposure, approximately 150 ROS molecules in the hit cell will be created within a fraction of a second exposure.⁷⁰ Thus, the 150 extra ROS molecules per “hit cell” from a radiograph literally represents less than a micropercentage (150/10 000 000 000) of the daily cellular ROS burden that occurs mostly from breathing air. This deems radiogenic cancer risks from the occasional radiograph examination irrelevant.

Siegel et al have stated that if the body lacked the ability to deal with ROS burden, we would have all succumbed to cancer already!⁶⁴ As discussed above, this does not happen; in fact, the opposite has been demonstrated. Lemon et al have documented increased life span in mice after receiving a single CT scan⁷⁷ and also in mice receiving multiple CT scans.⁷⁸ As mentioned, CT scans emit radiation levels in the low-dose range, and these are about an order of magnitude larger than exposures from conventional plain X-ray.

Radiography Is Below Inescapable Annual Background Radiation Levels

Radioactive materials are found throughout nature and include radon, soil, rock, water, food, air, and cosmic radiation from outer space, collectively known as “background” radiation. The International Atomic Energy Agency states that “Exposure to radiation from natural sources is an inescapable feature of everyday life in both working and public environments. This exposure is in most cases of little or no concern to society.”⁷⁹

The average exposure to background radiation levels in the United States (not including medical imaging) is 3.1 mSv/y.⁸⁰ Background levels may vary greatly based on geographic location and elevation, for example, the average annual background in Toronto, Canada, home of the first author, is about 1.59 mSv.⁸¹ The average worldwide background radiation dose is about 2.4 mSv/y.⁸²

Higher background radiation levels are incurred to residents living at higher altitudes, such as the Colorado plateau being about twice the background versus sea-level states. There are also specific regions in the world where background levels are much higher than average, including Ramsar (Iran), Guarapari (Brazil), Karunagappally (India), Arkaroola (Australia), and Yangjiang (China).

Studies on Ramsar, Iran, show that locals may be exposed up to 80 times the worldwide average natural background radiation exposure (260 mSv/y).⁸³ Of particular note is that of populations residing in these super high background radiation levels, there has never been any ill health effects ever documented to humans anywhere in the world.^{62,84,85} This is because it has been proven that those living in these high background areas show greater adaptive response than controls.⁸⁶ Thus, “claims that elevated natural background radiation levels lead to cancer or early childhood deaths are unjustified and misleading.”⁸⁷

The typical patient exposed to medical radiography will receive anywhere from 0.2 mSv (20 mrem) for a cervical spine series to 2.7 mSv (270 mrem) for a full-spine series (Table 1).⁸⁸ For comparison, radiation exposure from CT imaging ranges from 2 mSv for a routine head CT, to 8 mSv for a routine chest CT, to 15 mSv for a routine abdomen–pelvic CT scan.⁸⁹ Although technically comparing radiation from acute X-ray exposures to chronic background exposures is not directly comparable due to the body’s adaptive responses, it suffices to put the perceived risks of radiography into perspective. Thus, plain film radiographs are less than a year’s equivalent of background and, depending on where one lives, may equate to only a few days of natural and inescapable background radiation (Table 1).

Radiophobia Stems From Unwarranted Fears and False Beliefs

The LNT was born and adopted by the regulatory agencies during the cold war era (1950s). Great fears were created about any and all radiation ever since the historic atom bomb droppings on Hiroshima and Nagasaki during World War II. These events underpin the radiophobia that still persists today.⁹⁰

Radiophobia is prevalent and influences a parent’s decision to give consent for the imaging of their child. Patients who are informed about (theoretical) cancer risks associated with CT head scans, for example, are less likely to consent to their child’s imaging versus when they are not informed of the risks (70% vs 90% consent rate).⁹¹

There are no existing data supporting the contention that exposure to low-dose radiation as that given by radiographs

(or CT scans) contributes to the development of future cancers⁶²—in fact, there are only data that exist that show the opposite—less future cancers by upregulation of the body’s adaptive protective system.⁸⁷

The continued support of the LNT model by regulatory agencies and scientific advisory bodies, such as the NAS BEIR committee, NCRP, ICRP, and so on, only serves to propagate fear mongering by supporting the ALARA concept and the “Image Gently (children),” and “Image Wisely” (adults) campaigns.^{63,64} As stated by Siegel et al “Radiophobia is detrimental to patients and parents, induces stress, and leads to avoidance of imaging or suboptimal image quality, both producing misdiagnosis. This can only be overcome by rejection of the LNT fiction and its corollary principle, ALARA, and by termination of the Image Gently Alliance”.^{65(p867)}

Radiography Use Leads to Better Patient Outcomes

It must be stated that radiography remains the most cost-effective and practical imaging method for spine and posture assessment, for diagnosis, and for monitoring treatment progress in clinical practice. This is because magnetic resonance imaging (MRI) has limited availability, is not practical for common practice, and is costly.⁹² Further, other evolving technologies such as microdose X-ray by slot scanning devices⁹³ are not yet widely available. Conventional radiography, therefore, remains the primary spinal imaging procedure and its use has proven to be essential for achieving better treatment results for several spinal conditions and clinical scenarios.

In the treatment of scoliosis, it has been proven that treatment programs are more effective when tailored specifically to the patient’s spinal deformity rather than employing “cookie-cutter” conventional approaches.^{38,39} Noh et al determined that although a patient group had a reduction in Cobb angle after a “conventional exercise program” (focusing on core stabilization), superior results were obtained by a comparison group receiving a “corrective spinal technique” (CST) featuring patient-specific Schroth methods.³⁸ The CST group achieved greater improvements in Cobb angle, vertebral rotation, as well as total score, treatment satisfaction, and self-image subscale scores on the Scoliosis Research Society questionnaire 22). Monticone et al determined that traditional spinal exercises were able to maintain the health status (Cobb angle and health-related quality of life [HRQL]) in a group of patients with AIS with mild <25° scoliosis curves; however, the comparison group receiving a customized patient-specific (active self-correction, task-oriented spinal exercises, and education) program got better results achieving improvements in both reduction in Cobb angle and increased HRQL.³⁹

Regarding scoliosis treatment, it must be mentioned that it is essential to differentiate between functional and structural types (eg, hemivertebra) as treatment approaches will vary dramatically.⁹⁴ Obviously, this differentiation as well as the development of patient-specific, customized exercise programs deems radiography essential. Further, even in standard of care

approaches to scoliosis (ie, observation and bracing), radiography is mandatory; in fact, it is unethical to withhold bracing recommendations⁹⁵ to patients who are qualified candidates.⁹⁶

Rehabilitation programs aimed at correcting the cervical lordosis or lumbar lordosis require spinal imaging for the determination of appropriate diagnosis. Several randomized clinical trials^{17,18,21,34-36,97,98} have determined that in patients with either cervical hypolordosis having cervicogenic symptoms (eg, neck pain, headache, etc) or lumbar hypolordosis having lumbosacral symptoms (eg, lower back pain, sciatica, etc), “conventional” physiotherapy treatment programs (ie, stretching exercises, strengthening exercises, infrared irradiation (hot packs), manipulation, myofascial release, transcutaneous electrical nerve stimulation (TENS therapy, mobilization) results in only immediate and short-term improvement in outcomes (ie, reduced pain, increased range of motion, improved nerve function, improvement in HRQL). These initial patient outcome improvements from conventional physiotherapy methods, however, do not last and patient symptoms and outcomes regress toward baseline measures as quickly as 3 months without treatment. Alternatively, patients who receive either cervical or lumbar extension traction (ET) to increase the corresponding lordosis (as well as a cookie-cutter physiotherapy program) achieve better results initially and also remain well up to 1 year following the initial treatment. Patients getting ET also show improvements in lordosis measures, while comparison groups not getting ET do not. It is rationalized that the lasting, long-term improvement results from the structural improvements to the spine (ie, restoration of lordosis).¹⁷ Spine alignment can only be diagnosed by radiography.

Manual therapy approaches require radiographic imaging to ensure optimal force vectors for specific spinal joint manipulation.⁹⁹⁻¹⁰¹ In the practice of chiropractic, for example, in a sample of 500 patient radiographs, 91%, 70%, and 79% of patients may have radiographic-verified anomalies and pathologies that would alter treatment for the cervical, thoracic, and lumbar spinal areas, respectively.¹⁰⁰ Beck et al determined that up to one-tenth patients in a sample of 847 full-spine radiographs demonstrated absolute contraindication to spinal manipulation, including bone fracture, malignant tumor, abdominal aortic aneurism, and atlantoaxial instability.⁹⁹

Although a secondary consideration, patients are more satisfied when receiving radiographic procedures.¹⁰²⁻¹⁰⁴ This is probably because it is an expectation of patients to receive a radiographic assessment when presenting with spinal problems.^{105,106} One study, for example, found that 73% of patients expected X-rays for their lower back problem.¹⁰⁶ Thus, radiography use as a part of a comprehensive spinal assessment¹⁰⁷ has the added benefit of appeasing the patient.

As shown, radiography use in spine and posture rehabilitation leads to better outcomes when used in determining patient-specific treatment protocols, for example, in treating scoliosis patients as well as patients having cervical and lumbar spine hypolordosis/kyphosis; its use to differentiate functional from structural spinal disorders; and its use for screening for relative and absolute contraindications for introducing various force

vectors into the spine via manual spinal manipulation, postural traction, corrective exercises, and so on. Spinal radiography today stands as the most practical method to aid in the delivery of quality and superior, nonsurgical patient treatment for spinal disorders.

Risk to Benefit Ratio Is Always Beneficial for Routine Radiography

It may be more dangerous to not get a diagnostic imaging procedure when indicated than to “err on the side of caution” by avoiding the phantom radiation risk from trivial exposures. In fact,

actual risk arises from radiophobia through patient’s fear-driven imaging avoidance and physician-recommended substitution of alternate procedures . . . , true iatrogenic risk arises not only from such alternative procedures but also from misdiagnoses that are secondary either to patient refusal of medically indicated imaging or to nondiagnostic scans resulting from insufficient exposure.⁴⁸

Brody and Guillerman argue that there may be more risks with alternative imaging such as the need for sedation for pediatrics, geriatrics, or claustrophobic patients referred for MRI.¹⁰⁸ Further, exposures to general anesthesia have been deemed potentially detrimental to the cognitive development in the young and may contribute to accelerated cognitive decline in elderly individuals,¹⁰⁹ rendering MRI much more risky than radiography for certain patient populations.

Discovery of “incidental findings” (IFs) or previously undiagnosed medical conditions that are discovered unintentionally during radiography alone may confer a favorable risk–benefit balance. Rogers et al found the incidence of IF in children who had a CT scan for blunt head trauma to be 4%; importantly, 1% “warranted immediate intervention or outpatient follow-up.”¹¹⁰

Beck et al determined that the incidence of serious IFs (as found on full-spine radiographs in an outpatient clinic) deemed as “absolute contraindications” for manual therapy were not infrequent; these included fracture (6.6%; 1 in 15), malignant tumor (0.8%-3.1%; 1 in 32 to 1 in 125), abdominal aortic aneurysm (0.8%; 1 in 125), and atlantoaxial instability (0.6%; 1 in 167).⁹⁹ Also, as stated previously, up to 91% of patients may contain anomalies or pathologies, as determined by X-ray, that would alter originally intended treatment approaches.¹⁰⁰

As noted, IFs are common, particularly in their importance for manual therapy approaches to spinal disorders. Even though the incidence of serious IFs may be low, they do exist. This is particularly concerning for the incidence of malignant tumors. Cancer rates are continuing to rise,¹¹¹ and with this trend will be the increased odds of discovering malignancies as IFs on spinal imaging. This raises the issue of medicolegal implications and liability concerns from failing to identify a serious IF. Therefore, the treating provider should always be comprehensive in their

assessment and include radiography when indicated, as goes the old adage “no X-rays, no defense.”¹¹²

Further, standing radiography cannot be replaced by alternate methods. For example, CT scans and MRIs are most often performed in the recumbent position and postural data like sagittal balance, and exact spinal curve measurements will not be physiologic. For example, the measurement of lumbar lordosis differs between neutral standing and laying supine¹¹³; therefore, typical MRI lordosis data (in recumbent position) will be nonphysiologic and not confer useful information for spine therapists.¹¹⁴

A final argument is that since all mammals possess adaptive response mechanisms to overcompensate for radiation exposures in the levels given by routine radiography (as well as CT scans) and that these levels are not only within and below background radiation levels but also lower than optimal hormetic health-enhancing levels, thus, radiation exposures to our patients only present a zero risk—the equivalent of a “benefit to benefit ratio.”

If there is zero risk, then that leaves only benefit in a risk to benefit ratio. Therefore, as long as an imaging procedure can provide meaningful data in terms of diagnosis, differential diagnosis, monitoring treatment progress, IFs, patient satisfaction, and so on, the benefit will always outweigh a risk of zero.

Conclusion

Contemporary patient-specific spine and posture rehabilitation dictates routine radiography use to achieve superior patient outcomes. Common radiography exposures are below background levels and stimulate innate adaptive protection and are not harmful; they induce only 1 one-millionth the cellular damage than breathing air. All cancer risk estimates and dose minimizing campaigns including the ALARA concept are underpinned by the LNT hypothesis and are deceitful and fear-mongering. Radiography is a safe imaging method for routine use in patient assessment, screening, diagnosis, and biomechanical analysis and for monitoring treatment progress in daily clinical practice.


Declaration of Conflicting Interests

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