Clinical outcome and complications of thoracic and pelvic limb stump and socket prostheses

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Summary

Objectives: To describe the use, quality of life, compliance, complications, and outcome of animals fitted with stump socket prostheses.

Methods: Medical records of dogs fitted with a stump socket prosthesis were reviewed. Functional outcome, quality of life and complications were retrospectively assessed from an owner questionnaire.

Results: Thirteen stump socket prostheses (12 dogs) were fitted for a variety of reasons including trauma, congenital abnormalities, and neoplasia. Eight dogs had a good outcome overall and four a poor outcome. Quality of life (QOL) remained good or excellent in 10/12 dogs. Nine complications were seen in 7/12 dogs, most were manageable; surgical wound complications (n = 2) and pressures sores (n = 4) were the most frequently encountered. One dog suffered multiple complications. Thoracic and pelvic limb stump socket prostheses had a similar complication rate, however all animals with a poor outcome had a thoracic limb stump socket prosthesis; two were small breed dogs (under 10 kg) and two had bilateral thoracic limb abnormalities.

Clinical significance: Stump socket prostheses are feasible and versatile in animals. In correctly selected cases, good to excellent outcomes are possible. However, complications are frequent but often manageable. Further investigations are required into the risk factors for poor outcomes and prospective studies are required to assess changes in biomechanics, function, and QOL before and after fitting of a stump socket prosthesis. Until further evidence is available, careful consideration should be given before fitting bilateral thoracic limb stump socket prostheses or thoracic limb stump socket prostheses to small breed dogs.

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Introduction

Amputation is a commonly performed, well tolerated procedure in small animal practice for the treatment of neoplasia, peripheral neuropathies, trauma, infection, vascular compromise, and for irrevocable discomfort (1, 2).

The complication rate with proximal (coxofemoral disarticulation or forequarter amputation) amputations is low. Major complications include wound dehiscence, pneumonia, contralateral limb arthrosis, haemorrhage, dehiscence, and surgical site infection which is reported in 12.8% of dogs (1, 3). Poorly recognized complications include neuroma formation, cervical disc herniation and phantom pain (1). The long-term impact of amputation on global musculoskeletal function in animals is not reported. However, given the changes to ground reaction force and contact times of the remaining limbs, it is possible that accelerated degenerative changes may occur in the remaining joints as a result of altered load sharing (4).

There is a cohort of veterinary patients for which amputation is not an option, for example those with concurrent severe orthopaedic disease or neuropathy, or due to owner objections. Consequently, limb sparing surgery has been adopted in veterinary medicine, most commonly for osteosarcoma involving the distal radius (5). Techniques include cortical allografts, endoprostheses, pasteurized autograft, or vascularized ulna transposition (6–8). Additionally, there are reports of femoral and humeral limb salvage procedures (9, 10). Palliative radiation and stereotactic radiotherapy can also be alternatives to amputation for management of osteosarcoma (11, 12).

Alternatives to amputation also include osseointegrated implants which have been used successfully in humans and animals, and stump socket prostheses. These techniques are not limited to neoplasia management (13–15). Potential reported advantages of osseointegrated implants include improved comfort, no delay in load transfer, improved proprioception, and avoidance of stump socket interface problems that are commonly encountered in stump socket prostheses (15, 16). However complications including fracture, infection, skin breakdown, and aseptic loosening are all reported. Recovery from osseointe-

grated implant surgery can be prolonged (15, 16).

The reported complications encountered in human stump socket prostheses are influenced by the underlying disease but include seroma formation, wound dehiscence, stump infection, and dermatological issues at the stump prosthesis interface (17-20). A delay in fitting of the prosthesis is also negatively correlated with satisfaction and frequency of prosthesis use (21).

Recently, a specific veterinary stump socket prosthesis has become commercially available for use following subtotal amputations; the claimed advantages of this prosthesis[a] are the relative affordability, simple application, and minimal convalescence required (22). The aims of this study were to report the use of stump socket prostheses in animals and the associated compliance, functional outcome, quality of life (QOL), and complications following prosthesis application.

Methods

Case records of all dogs that had a stump socket prosthesis applied at Dogs in Motion (Victoria, Australia) and University of Bristol (Bristol, UK) were retrieved and reviewed. The stump socket prostheses used in these animals were manufactured initially by creating a fibreglass impression of the limb which was used as a mould to create a plaster replica of the limb or digitally scanned into computer-aided design software. The resultant plaster or digital model was then adjusted, and a polypropylene thermoplastic was then vacuum-formed around the model. The final stump socket prosthesis incorporated closed cell foam padding and support appropriate for the individual case (▶Figure 1) (22). They were secured with heavy-duty hook and loop straps. A small simple stump socket prosthesis weighed approximately 200 g but the prosthesis weight varied depending on the individual animal.

a OrthoPets, Denver, CO, USA

Inclusion required complete medical records including breed, date of birth, sex, date stump socket prosthesis was fitted, affected limb, reason for fitting, type and level of prosthesis, details of any surgical procedures performed, a minimum of six months follow-up, and owner consent to participate in a follow-up survey.

Owners were requested by telephone to complete a questionnaire which was sent via email; there was no incentive offered for completion of the questionnaire. In the cases where the questionnaire was not returned, the owners were telephoned again to confirm contact details and an offer was made to resend the questionnaire by mail or email. No telephone interviews were conducted.

The questionnaire contained sections relating to the fitting, compliance and tolerance, function and complications associated with the stump socket prosthesis as well as QOL. Owners were encouraged to insert comments in the space provided. Currently there are no validated questionnaires for evaluation of stump socket prostheses in animals, although there are validated veterinary questionnaires for example for assessment of QOL for other orthopaedic indications (23).

A validated questionnaire aimed at evaluating QOL in dogs with pain secondary to cancer was modified for use in this study (24). This provided seven questions using a Likert scale with each answer scored between zero and three, a lower score indicating more severe problems (25). The total score of these seven questions contributed to a QOL score, with a maximum of 21. Scores of 19 or above were deemed to represent excellent QOL, 17 to 18 good, 15 to 16 fair, and below 15 poor QOL. Owners were additionally asked to categorize and comment on their pets QOL.

The final QOL score assigned to each patient was derived from assessing both the owner-assigned categories and comments and the question generated QOL score in tandem. A final score of excellent, good, fair or poor was assigned by selecting the lowest category recorded from either the QOL score or the owners category and comments. For example, if the QOL score was 18 (which would represent good) but the owner categorised the dogs QOL as fair, the overall QOL was recorded as fair.

Questions about fitting included: time from amputation or injury to fitting, time to become accustomed to the prosthesis, and difficulty in fitting. All questions had a six level Likert scale ranging from one to two weeks to greater than six months, or very easy to very complex.

A range of questions to gain information on the compliance and tolerance of the stump socket prosthesis included: the duration the stump socket prosthesis was worn during an average day, time taken to reach this duration, and subjective assessment of tolerance of the stump socket prosthesis. These questions were askedin relation to both the initial fitting and once the animal had become accustomed to the stump socket prosthesis. Function was assessed on an adjectival scale with a series of questions investigating jumping up or down and duration of exercise comparing before and after fitting of the stump socket prosthesis. See the online ▶Supplementary Material for for the full questionnaire (available at www.vcot-online.com).

Complications were assessed from the case records and owner questionnaire. Categorical questions about expected complications including seroma, infection and wound complications, as well as open questions requiring comments on complications were asked.

A dichotomous category - overall outcome - was created based on the results of the survey, and defined as good if the animal continued to use the stump socket prosthesis at time of questionnaire completion, tolerated the stump socket prosthesis mostly or completely, continued to exercise at pre-fitting levels, had an overall good or excellent QOL, and no long-term complications. Other outcomes were defined as poor.

Data were described with descriptive statistics and normality was assessed with Shapiro-Wilk tests. The data mean (± standard deviation) and median (and range) were presented as appropriate. Categorical data were described as fractions or percentages of the population.

Results

The owners of 12 out of 14 dogs fitted with stump socket prostheses returned completed questionnaires. This resulted in 13 stump socket prostheses fitted to 12 dogs that met the inclusion criteria, 11 from Dogs in Motion (Victoria, Australia) and one from University of Bristol (Bristol, UK). Median age was three years (4 months – 9 years) and mean body weight was 18.1 kg (standard deviation: 11.2; range: 4.1 – 45.0 kg). Dog breeds were Border Collie (n = 2), German Shepherd Dog (n = 2), St. Bernard, Golden Retriever, Toy Poodle, Pug, Scottish Collie, Shar Pei, Staffordshire Bull Terrier and Tibetan Terrier. Five were female (four neutered) and seven were male neutered.

Eight thoracic limb stump socket prostheses (including one dog with bilateral stump socket prostheses) and five pelvic limb stump socket prostheses were fitted. ▶Table 1 summarizes the location, number of stump socket prostheses, and reasons for fitting the stump socket prostheses. Of the 12 dogs, two were advised to have stump socket prostheses fitted due to bilateral abnormalities, one with bilateral thoracic limb congenital abnormalities and the other post-failure of bilateral pancarpal arthrodesis and bilateral subtotal amputation at the referring veterinary practice prior to referral. The dog with neoplasia had concurrent cruciate ligament disease in the contralateral limb. The remaining nine were owners who had refused the advice of a routine amputations due to concerns over function or cosmesis.

One dog had the stump socket prosthesis fitted within four weeks of amputation, the majority had the stump socket prosthe-

Figure 1 Example of pelvic limb stump socket prosthesis.

Table 1 Summary of the number of stump socket prostheses (SSP) fitted at each level (either proximal or distal, thoracic or pelvic limb), reason the stump socket prosthesis was fitted, overall outcome, and the number of animals that experienced complications.

Level of SSP	Number SSP	Reason for SSP				Outcome		Number complications
		Congenital	Trauma	Surgical complication	Neoplasia	Good	Poor	
Carpus or distal	5	2	3			2	3	2
Antebrachium	3	1		2		2	1	4
Proximal intertarsal joint or distal	2	1	1			2		1
Tarsocrural joint or proximal	3	2			1	3		2

sis fitted at least two months post amputation (between 2 and 4 months [n = 4] or >6 months [n = 4]). Time between fitting of the stump socket prosthesis and completion of the questionnaire was variable, but ranged from six months to four years with a median of 11 months. Nine of the 12 owners surveyed found the stump socket prosthesis easy or moderately easy to fit and none found the fitting complex. None of the dogs wore the stump socket prosthesis overnight.

The ability to jump up and down and duration of exercise were measures used as a surrogate for functional outcome. Ability to jump up and down compared to before fitting of the stump socket prosthesis is summarized in ▶Table 2. Seven of the dogs were able to exercise to the same level and one slightly more than before fitting of the stump socket prosthesis. Two were able to exercise less following fitting of the stump socket prosthesis; both of these dogs had a poor outcome and complications.

Tolerance was reported to be instant for four dogs. Of the remaining eight stump socket prostheses; one became accustomed to the stump socket prosthesis within two weeks, two within a month, two between one and two months, and a 5 Kg Pug required more than six months. Two of the four dogs with a poor outcome never tolerated the stump socket prosthesis; one of these owners persisted with the stump socket prosthesis for four weeks, the other abandoned the stump socket prosthesis very quickly as it was deemed too heavy. The remaining two dogs with a poor outcome continued to use the stump socket prosthesis for four months and two years respectively. Veterinary follow-up with these cases was performed by the referring veterinarian, specialist surgeon, or a veterinary physiotherapist on an individual basis as required. Input from a veterinary physiotherapist following fitting of the stump socket prosthesis was recommended in all instances.

Table 2 For the animals that tolerated the stump socket prosthesis, the change in ability to jump up and jump down compared to before the stump socket prosthesis was fitted is shown.

	Jumping down	Jumping up
Much harder	1	2
Slightly harder	4	3
No different	4	4
Better	1	1

Time to reach maximum use of the stump socket prosthesis was almost identical to the time to become accustomed, i.e. once accustomed, the stump socket prosthesis was used maximally. The median time the stump socket prosthesis was worn daily was six to eight hours and average number of hours worn on a representative day for each animal is shown in ▶Figure 2.

Median QOL score including all dogs was 19. One dog had a score of 10 – the dog with bilateral thoracic limb stump socket prostheses. All other dogs had a score of good or excellent, however one owner rated the overall QOL as fair without explanation. This was a small breed dog with a traumatic amputation of the right thoracic limb, which did not tolerate the stump socket prosthesis. Overall QOL was therefore categorized as good or excellent for 10/12 (including two dogs with a poor overall outcome), fair and poor for one respectively.

Seven out of the 12 dogs suffered a total of nine complications (▶Figure 3). The majority were self-limiting. Pressure sores were suffered intermittently in four dogs following excessive use or poor stump socket prosthesis fit. One stump hardened with time, which improved but did not resolve the pressure sores. On occurrence, three were managed conservatively by avoiding the use of the stump socket prosthesis for up to three days. The fourth continued to use the stump socket prosthesis but a sock was used to protect the stump and allow healing. None required regular veterinary involvement. Of the two dogs with wound related complications, one suffered surgical wound dehiscence, which healed uneventfully with conservative management and had no further complications. The second suffered surgical wound dehiscence, which was compounded by a poorly fitting stump socket prosthesis. The poor fit was suspected to be

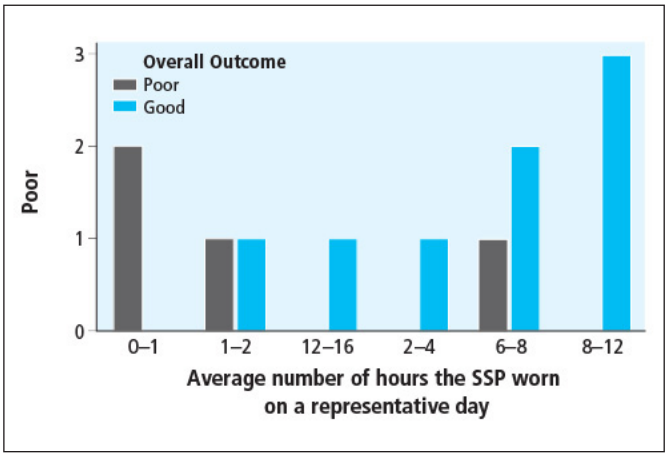

Figure 2 Average number of hours each animal would use the stump socket prosthesis (SSP) for a normal representative day in relation to the overall outcome. The median time the SSP was worn daily was six to eight hours. The outlier with a poor overall outcome represents the dog with bilateral thoracic limb SSP.

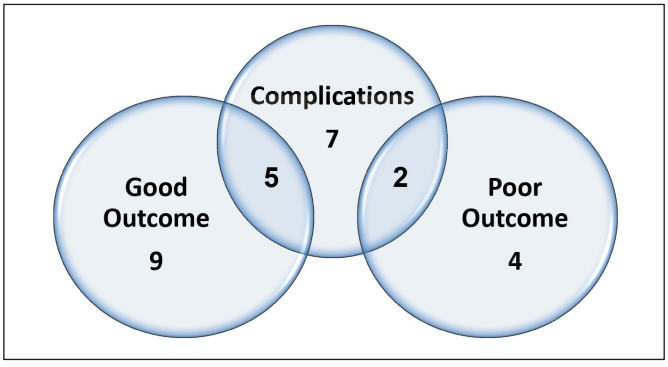

Figure 3 The number of dogs that suffered complications is shown in relation to the overall outcome.

a result of difficulties in the casting procedure for manufacture of the stump socket prosthesis due to small chondrodystrophic limbs. This dog was 10 Kg and the stump socket prosthesis was relatively heavy, and it was one of the two dogs with both a poor outcome and complications. Following abandonment of the stump socket prosthesis, this dog had a good outcome with a neoprene boot. This dog and the dog with multiple complications required repeated veterinary intervention at significant additional financial cost. The dog with multiple complications following failed bilateral pancarpal arthrodesis suffered recurrent pressure sores every few weeks, which commonly became infected. This dog required periods with systemic and topical treatments, veterinary intervention and periods without one of the stump socket prostheses. There was also initial wound dehiscence and a seroma formation. This dog was ultimately euthanatized due to poor QOL two years after initial fitting of the stump socket prostheses.

Overall outcome was good in eight of the 12 cases – all of these dogs still used the stump socket prosthesis daily at the time of data acquisition. All four dogs with poor outcomes had thoracic limb stump socket prostheses (1 had a bilateral thoracic limb stump socket prosthesis). Two were small breed dogs under 10 kg, both of these owners commented that the stump socket prosthesis appeared too heavy. One of these small dogs and a fourth dog received stump socket prostheses that ultimately were a poor fit.

Discussion

Eight of the 12 dogs fitted with a stump socket prosthesis had a good outcome. The absence of objective exercise data makes direct comparison difficult, but this outcome is similar to the 73–91% of dogs which are expected to return to pre-surgical activity following amputation (2, 26). The number of dogs that had a stump socket prosthesis fitted due to owners refusing amputation may positively bias this figure.

There are too many variables within the data to clearly conclude how function is affected by the fitting of a stump socket prosthesis. Changes in jumping are likely to be multifactorial but reasons could include comorbidities, the weight of the stump socket prosthesis, reduced biomechanical advantage, or pain associated with the stump. Despite this reduced ability to jump, owners did not perceive reduced function, duration of exercise, or QOL. The dogs with a congenital abnormality and good outcome are the most likely group to display improved function but there are too few cases (n = 3) to make any inferences regarding an absence of improved function.

Jumping was included as a semiquantitative measure of outcome in the absence of kinetic or kinematic data. It could be possible that jumping could influence outcome by contributing to complications such as pressure sores. There are too few cases here and unsuitable questionnaire responses to explore any possible association, but future investigations could provide more guidance to owners to minimize risk of complications.

Trauma and congenital abnormalities were the most common aetiologies in this study rather than neoplasia, which was most frequent in a recent amputation study (26). Perhaps this is a reflection of either increased versatility of the stump socket prostheses or increased chance of comorbidities associated with these aetiologies. Additionally, the low number of neoplastic aetiologies may also be influenced by other well described options for limb salvage of the distal radius (6).

Encouragingly 10 of the 12 dogs in this study recorded good or excellent QOL. This is consistent with a previous report in which 88% of dog amputees returned to normal or near normal QOL (26). The higher complication rate identified with stump socket prostheses compared with a routine amputation does not appear to affect overall QOL.

It is possible the low QOL score for the dog with bilateral stump socket prostheses is representative of the duration the stump socket prostheses were fitted, perhaps due to excessive weight bearing on both stumps. However the poor QOL score could be more representative of the latter experience of the stump socket prostheses prior to euthanasia. Until further evidence is available, bilateral thoracic limb stump socket prostheses cannot be recommended.

It has previously been shown in human cancer survivors that QOL questionnaire completed via a telephone interview will have a higher score than if completed via mail (27). It is unknown if this is also true for pet owners, but possibly the QOL score for the dog with a fair QOL score may have increased had there been a follow-up call (27).

Two dogs also had good and excellent QOL scores in spite of not tolerating the stump socket prostheses. This may be a proxy for QOL following amputation or a reflection of congenital abnormalities. Alternatively, the QOL questionnaire was based on a questionnaire designed to assess QOL secondary to cancer and may not have been optimized to detect QOL abnormalities in dogs with congenital malformations.

Furthermore, the questionnaire was not designed to assess QOL from an orthopaedic perspective, but the questions posed were sufficiently relevant that it was deemed appropriate to use. Additional areas of interest include the effect of complications on QOL, change in exercise, or daily duration of use of stump socket prostheses over time. Due to the variability in follow-up, problems with long-term recollection and difficulty in data interpretation due to low numbers and variable follow-up, this data was not collected, but all warrant further investigation. This limitation is not unique to this study and highlights limitations of using non-validated questionnaires. The large proportion of stump socket prostheses fitted due to owners refusing amputation is an additional source of bias in their interpretation of outcome, and could have positively influenced the results of the questionnaire.

The surgical wound complication rate is similar to previously reported wound complications following amputation (3). This is encouraging considering more distal amputations are associated with a higher incidence of wound problems in people (17). Possibly the sample size is insufficient to detect a difference. Recommendations for surgical techniques in people include

avoiding osseous spurs, ensuring scars are mobile and distant from areas of maximum pressure and movement – often using a myocutaneous flap, maintaining muscle attachment to the periosteum, and shaping the muscles to provide a cushion over the bone end but without excessive muscle mass to interfere with stump socket prosthesis fitting as well as burying nerve ends to minimize neuroma formation (28).

Human studies recommend a target of less than 60 days from amputation to prosthesis fitting as a delay is negatively correlated with outcome (21). Unfortunately, the limitations of a retrospective study and a high proportion of congenital abnormalities in the population prohibited further analysis but this merits future investigation.

It is possible that dogs with one stump socket prosthesis may not load the affected limb as they would a normal limb, but bilateral configuration may force near normal loading of both thoracic limbs, possibly increasing the likelihood of pressure sores.

An inherent limitation of the stump socket prosthesis manufacturing process is the accuracy of the initial cast, a poorly representative cast will have the subsequent effect of an imprecisely fitted stump socket prosthesis. The small and abnormal anatomical configuration of some veterinary patients can make it difficult to cast accurately; the inability to obtain a representative cast may be a relative contraindication for a stump socket prosthesis. Newer technologies such as 3D printing may become a way to avoid such problems. Repeatable accuracy in daily stump socket prosthesis fitting is also required.

All dogs with pressure sores had a good overall outcome and continued to receive the same amount of exercise as before stump socket prosthesis fitting, demonstrating that pressure sores are a manageable issue. Further studies are required to investigate any potential link between activity levels and development of pressure sores. In people it has been suggested more active people are at greater risk of developing stump skin issues (29). Many strategies are employed to manage pressure sores in humans, involving management of underlying comorbidities and often by an integrated multidisciplinary team. Translational aspects that could be used in veterinary medicine include the avoidance of weight bearing when a pressure sore is present, modification of the stump socket prosthesis to optimize fit and alter shear forces for example by the addition of a silicone sleeve (30). Ensuring patient tolerance of materials should be considered as dermatological conditions such as contact dermatitis can be a significant problem (31).

Weight of the patient may also affect outcome; one 5 Kg dog required more than six months to become tolerant to a stump socket prosthesis, but went on to have a good QOL without complication. It is possible the other two dogs under 10 Kg had insufficient time to become tolerant to the stump socket prosthesis. Alternatively the weight of the stump socket prosthesis, or differences in biomechanics between thoracic and pelvic limbs, may require a larger dog to achieve a good outcome with a thoracic limb stump socket prosthesis. It is possible that these complications are independent of weight and represent a genuine difference between thoracic and pelvic limbs. Body condition score has been shown to have a negative correlation with QOL following amputation (26). Body condition score was unfortunately not recorded as data were collected prior to this publication. Feasibly, a stump socket prosthesis may improve the QOL of high body condition score dogs following amputations. However, further investigations are indicated as overweight humans have poorer mobility and prosthetic use (32).

Thoracic and pelvic limb stump socket prostheses appear to have a similar complication rate however, all dogs with a poor outcome had a thoracic limb stump socket prosthesis. This finding could be a reflection of small numbers: two dogs having bilateral disease and the remaining to being less than 10 Kg.

The limitations of this study include the retrospective nature, which is magnified by the small sample size and precluded the use of analytical statistics. Study design prevented the use of objective functional outcome measures. The surrogate markers used here, the change in ability to jump up and down, and the duration of stump socket prosthesis use have limitations including susceptibility to owner bias, being semiquantitative measures, and may not be fully representative. The greater number of dogs with congenital abnormalities is an additional limitation; jumping ability and exercise duration pre-fitting of the stump socket prosthesis may not have been comparable to those dogs that had an amputation. Force plate analysis and kinematic data would be needed for more objective outcome measures, and ideally used to investigate function before and after amputation and following fitting of a stump socket prosthesis. Another limitation resulting from study design is the time from fitting of the stump socket prosthesis to completion of the questionnaire; this could induce inaccuracies in owner responses and positive bias. The accuracy of owners to correctly categorize complications may also provide a limitation, however interpretation of owners comments cross-referenced with medical records minimizes the chance of non-representative data.

The fitting of a stump and socket prosthesis may provide a successful alternative for dogs that are poor candidates for amputation. Further investigations are required to identify risk factors for poor outcome. Pressure sores and non-tolerance were the most common complications. Until further information is available, careful consideration is recommended before fitting thoracic limb stump socket prostheses to small dogs or those with bilateral thoracic limb disease.

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Author Contributions

AP was involved in the study design and data analysis and interpretation. EK and AH were involved in the study conception, study design, and data analysis and interpretation. EB and MM were involved in the study conception and acquisition of data. KP was involved in the data analysis and interpretation. All authors participated in

the drafting or revising of the manuscript and approved of the submitted version.

Conflict of interest

There are no conflicts of interest to declare.

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