Posture Abnormalities as Indicators of Musculoskeletal Disorders in 12 Zoo Elephants – a Visual Guide

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Abstract. Musculoskeletal disorders represent one of the many challenges in elephant care. In contrast to other species, elephants rarely express distinct lameness despite severe lesions. Therefore, alterations in their posture and weight distribution while standing seem to be easier to recognize. To raise the practitioners' awareness of these changes and facilitate the earliest possible recognition, a visual guide was compiled. Pictorial documents were collected by the author while visiting 70 elephant-keeping facilities across Europe. The resulting guide provides a description of the healthy baseline state and a series of common alterations. Awareness for corresponding visual cues will further improve monitoring of musculoskeletal disorders in elephants under human care.

Introduction

Musculoskeletal disorders represent a frequent health concern in elephants under human care (Mikota *et al*. 1994; Miller *et al*. 2016; Regnault *et al*. 2017; Bansiddhi *et al*. 2019; Edwards *et al*. 2019; Wendler *et al*. 2019). Apart from lesions in the structures of the elephant's foot, degenerative joint disease and presumably correlated conformational abnormalities have been reported in zoo elephants (Luikart & Stover 2005; Kaulfers *et al*. 2010; Johnson *et al*. 2018).

Degenerative joint disease is a progressive joint disease characterized by breakdown of cartilage and alterations of the underlying bone. Apart from clinical examination, radiography presents a practicable diagnostic tool in adult elephants for the foot and the carpal respectively tarsal joint (Hittmair & Vielgrader 2000). More proximal joints are difficult to investigate radiographically due to the thickness of the surrounding tissue (Hittmair & Vielgrader 2000; Kaulfers *et al*. 2010). Thermography has been shown helpful to diagnose inflammatory joint conditions, although further research is needed to validate this approach (Schmidt-Burbach 2009; Miller *et al*. 2016). Degenerative joint disease is supposed to occur more frequently under the circumstances of captivity compared to free-ranging elephants, although the underlying causes have not been fully investigated so far. Management and environmental factors such as substrate, enclosure size, activity level, stereotypic behaviour and overweight have been considered and at least partially confirmed to impact foot and joint health in captive elephants (Haspeslagh *et al*. 2013; Miller *et al*. 2016; Edwards *et al*. 2019; Wendler *et al*. 2020). Therefore, foot and musculoskeletal disorders present a relevant health concern in elephants living in human care. To address corresponding management aspects and improve them subsequently is critical to assure captive elephant welfare (Poole & Granli 2008; Meehan *et al*. 2019).

Although lameness is considered the most important clinical sign of musculoskeletal disorders in other species, elephants have been shown to rarely express distinct lameness patterns (Fowler & Mikota 2006; Lewis *et al*. 2010). This might even be the case in severe lesions (Lewis *et al*. 2010). Nevertheless, lameness is still postulated as the most important clinical sign associated with foot and joint diseases in elephants (Fowler & Mikota 2006). It is up to speculation whether elephants do really not express obvious lameness, or the keepers and veterinarians are not sufficiently skilled to recognize it. With respect to the painfulness of musculoskeletal disorders, the determination and monitoring of more subtle indicators compared to lameness would be extremely helpful in the medical management and care of elephants. The latter might be of peculiar relevance in circumstances where diagnostics such as radiographic imaging or thermography are not available.

Material and methods

In the course of another population-wide research project (Schiffmann *et al*. 2018a, 2019), 70 elephant-keeping facilities across Europe were visited from 2016–2019. While visiting these institutions, pictorial documents were collected opportunistically. Where available, information regarding musculoskeletal disorders of individual elephants was recorded in parallel in a non-standardized manner. In order to complete these datasets, necropsy reports and published necropsy data of deceased elephants were collected as well if accessible. Collected pictures were analyzed regarding common posture patterns and potential visual indicators for musculoskeletal disorders. Based on these data a visual guide facilitating the assessment and monitoring of affected elephants was compiled.

Results

Data collection led to pictorial data of 12 individual elephants with confirmed musculoskeletal and/or foot disorders according to pre-mortem (all individuals) and/or post-mortem (available in 7 individuals) findings. This sample contains 3 female African elephant (*Loxodonta africana*) and 9 (2 male and 7 female) Asian elephants (*Elephas maximus*) living in zoological institutions across Europe. They ranged in age from 35 to 60 years. At the time of this report, only two of these elephants, namely one male and one female Asian elephant, were still alive.

The photographs showed recognizable alterations in weight distribution of varying severity compared to a normal standing posture (Figs. 1 & 2). It was observed that this weight shifting occurred in a lateral (Fig. 1) as well as in a frontal perspective (Fig. 2). An equivalent of this relieving behaviour could be recorded in elephants that repeatedly expressed specific postures of relief (Figs. 3 & 4), or even intermittently kept one leg lifted completely from the ground for a considerable amount of time (Fig. 5). Furthermore, obvious joint deformities of varying configuration were recorded (Fig. 6). Interestingly, exclusively the carpal joint was affected by severe deformities. This corresponded with information from post-mortem reports, where these joints were most often mentioned to show signs of degenerative joint disease (unpublished data). A less obvious but impressive indicator of musculoskeletal alterations was present in terms of secondary traces on the skin of one elephant (Fig. 7).

Figure 1. **(a)** Normal standing posture from a lateral view in a male Asian elephant. **(b-f)** Stages of increasingly shifting weight to the hind legs in order to relief the affected front limbs. Note that photographs represent animals that are standing, not animals in movement.

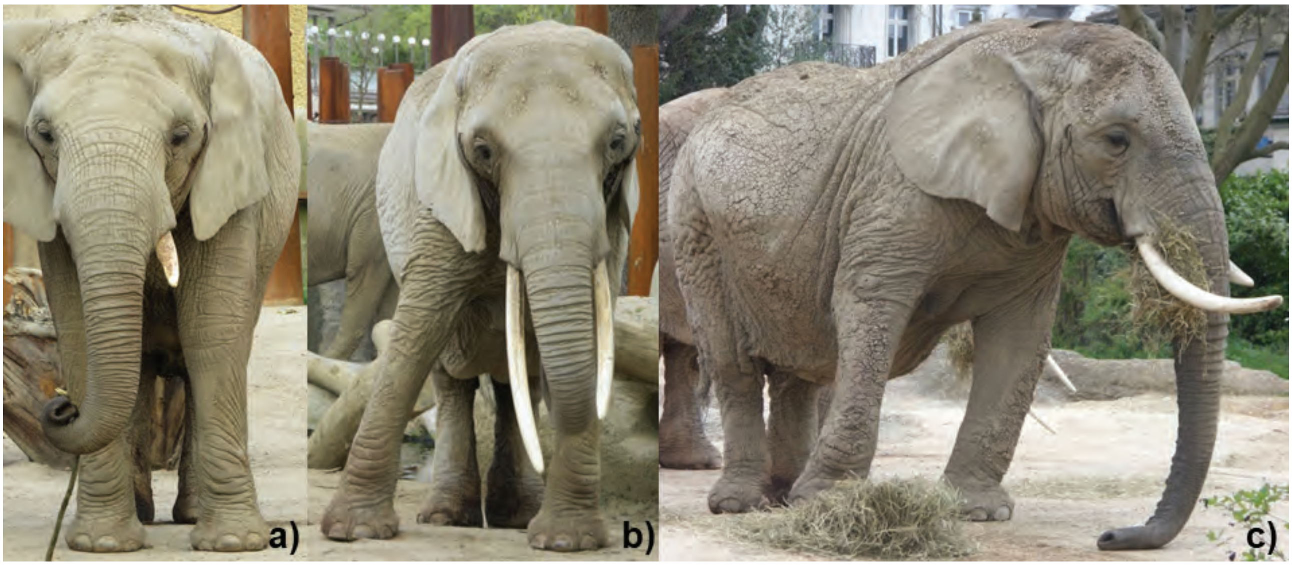

Figure 2. **(a)** Normal standing posture from a frontal view. **(b, c)** Relief of the right front leg by placing it laterally and shifting body weight to the left side in order to relief the right front leg in two female African elephants. Note: In both affected elephants shown here moderate to severe degenerative joint disease in the carpal joint of their right front leg has been confirmed post-mortem.

Figure 3. Specific postures of relief in an individual African elephant suffering from degenerative joint disease in the carpal joints. Note: Although the affected foot is consistently placed in a similar position, the elephant makes use of various environmental structures to do so.

Figure 4. Temporary relief of a back leg by **(a)** placing it on a rock, **(b)** crossing it with the weight-bearing leg, and **(c)** by leaning with the hip/pelvic bone against a wall (note the arrow).

Figure 5. Geriatric female and male Asian elephants intermittently keeping one front foot in a lifted position while eating. In order to maximally relieve this extremity, both elephants repeatedly keep it from the ground for variable amounts of time (seconds up to several minutes).

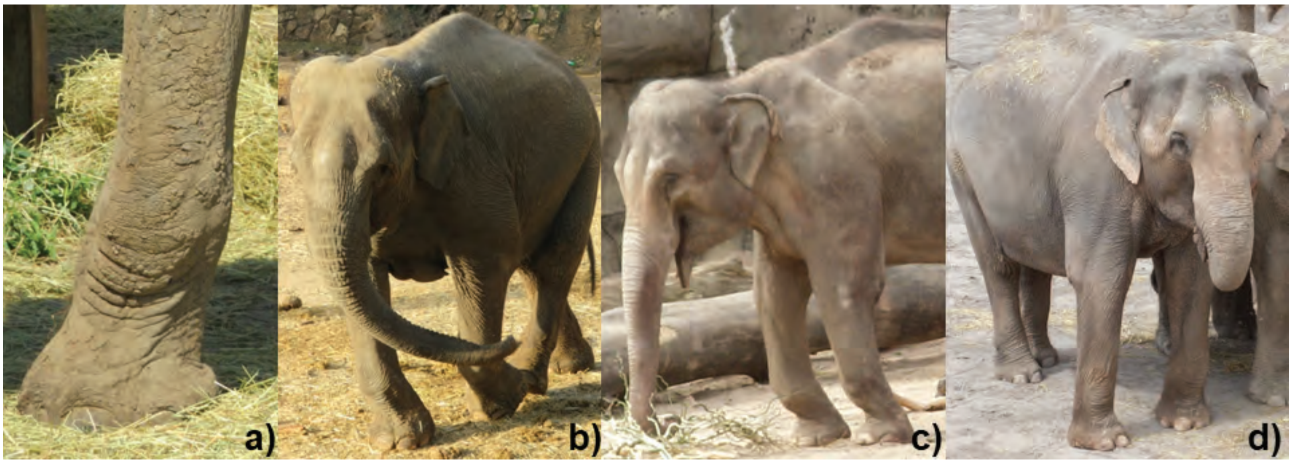

Figure 6. Example pictures for various deformities of the carpal joint: **(a)** Lateral deviation (valgus deformity) of the foot in the right front leg of a female African elephant; **(b)** medial deviation (varus deformity) of the foot in the right front leg of a female Asian elephant; **(c)** caudal deviation of both carpal joints in a female Asian elephant; **(d)** inwards rotation of both front legs in a female Asian elephant.

As mentioned above, general or local stiffness of an elephant's gait might be observed, but seems only common in severe cases and difficult to capture on pictorial documents. Although I did not focus on gait patterns here, the application of slow motion video recordings might reveal more information on subtle lameness patterns and promote this approach as a diagnostic tool.

Discussion

Although compared to other species, distinct lameness patterns are less commonly observed in elephants (Fowler & Mikota 2006; Lewis *et al.* 2010), they do express specific alterations in their posture indicative of musculoskeletal disorders. These alterations are visually perceptible for the experienced observer. To facilitate the corresponding assessment and evaluation, attentively checking the following aspects is recommended.

1. Weight distribution and posture in a standing position

An elephant with a healthy musculoskeletal system will distribute its body weight evenly on its four legs, although the front legs do physiologically bear more weight than the hind legs (Schmidt-Burbach 2009; Panagiotopoulou *et al.* 2012). The leg joints of an elephant allow a distinct range of motion while walking, but show a column-like conformation when the elephant is standing (Fig. 8a). The latter means that in a normally standing elephant the carpal, elbow and shoulder joints of the front and the tarsal, stifle and hip joints of the hind leg are positioned in a vertical axis (Figs. 1a, 2a & 8a) (Weissengruber *et al.* 2006; Ahasan *et al.* 2016). This axis is consistently visible from a lateral as well as a frontal or rear view. When suffering from irritation or pain in a specific foot or leg, the elephant will change from this normal posture to a position allowing it the relief of the affected structure. This may become obvious by shifting weight in a corresponding direction (Figs. 1, 2 & 10) or placing the affected foot or leg out of the weight bearing vertical axis (Fig. 2). Additionally, a kyphotic posture of the thoracolumbar spine, in order to relieve the front legs, may be observed (Fig. 8). In contrast to the African species, this sign will be hard to detect in Asian elephants due to their physiologically kyphotic spine conformation. Such changes in weight distribution and posture due to painful conditions in feet or legs are well known for domestic species such as horses and cattle (Hood *et al.* 2001; Poursaberi *et al.* 2010) (Fig. 9). Luikart & Stover (2005) demonstrated the association of

Figure 7. Secondary traces of musculoskeletal disorders on the skin of a geriatric female Asian elephant. The sores and ulcerations developed after the elephant stopped lying down during the night and leaned against a vertical bar for a prolonged time to relieve her affected front legs. Note: The traces are on the same vertical level as the bar in the elephant's night house.

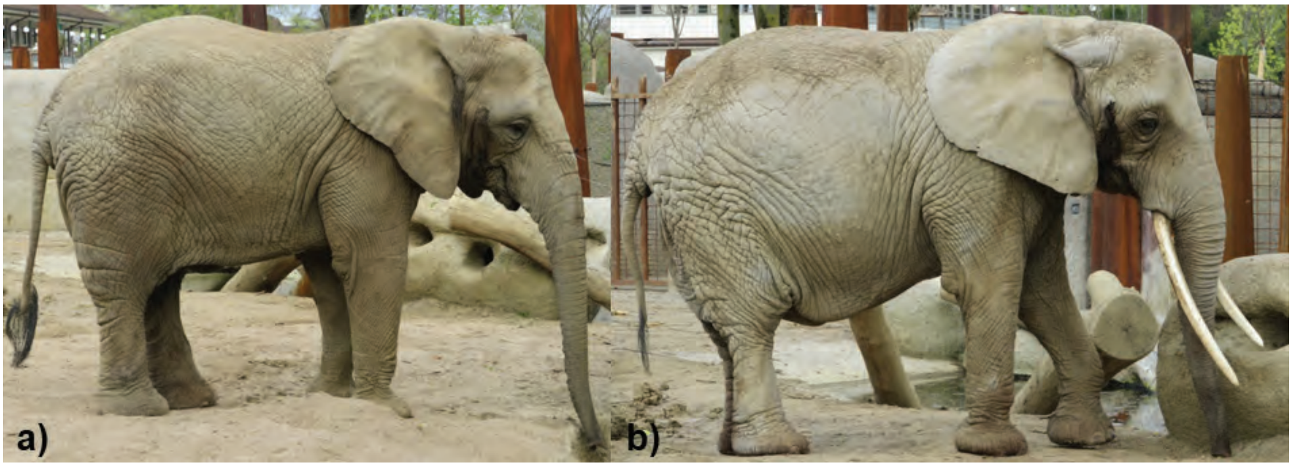

Figure 8. (a) Normal standing posture in a healthy female African elephant. Note the columnar-like conformation of the legs with the joints aligned in the weight-bearing vertical axis. **(b)** Caudal weight shift in a standing female African elephant suffering from degenerative joint disease in the carpal joints. Note the deviation of the joint position from the vertical axis and the kyphotic shape of the thoracolumbar spine.

abnormal or unequal weight distribution with the occurrence of chronic untreatable sole ulcerations in two Asian elephants. According to their report, abnormal weight distribution patterns should be considered of relevance since their underlying causes might lead to secondary diseases.

2. Positions to relieve a specific limb or joint

In elephants, various postures during standing rest have been reported and are characterized by giving some body weight to external structures by leaning against or placing a body part (trunk, tusks, head, leg) on them (Schiffmann *et al.* 2018b) (Fig. 10). These behaviours should not a priori be considered indicative of any musculoskeletal health issue. Rather, interpretation should be based on their frequency and intensity of occurrence. As an example, even sub-adult elephants with a perfectly healthy locomotor system may show postures with relieving one leg during daily resting phases. In contrast, elephants suffering from musculoskeletal disorders will express such specific positions much more frequently and independent of resting phases, always relieving the same leg. Furthermore, they may be observed to use various structures, depending on the enclosure they are kept in (Fig. 3). Johnson *et al.* (2018) report frequent weight shifting between the right and left front

Figure 9. Comparison of the abnormal standing posture in a horse suffering from painful laminitis and a geriatric elephant with severe front foot disorders. Note the caudal shift of body weight to relieve the front legs. Horse picture by Dr. med. vet. Hiltrud Straßer.

Figure 10. A geriatric female African elephant placing her tusks on a horizontal bar. In this individual degenerative joint disease in both carpal joints has been confirmed post-mortem. Note that the elephant expresses this specific position also while eating branches and therefore not exclusively during resting phases.

feet in a female Asian elephant suffering from a difference in leg length. After improving the latter by the application of glue-on shoes, the shifting behaviour stopped immediately. Intensity and frequency of specific relieving positions may present a helpful indicator for the progression and also treatment effect when monitoring the condition of an affected elephant.

3. Joint deformities

With respect to the lack of evidence-based reports, it can only be speculated why elephants show joint deformities and presumably associated degenerative alterations mainly in their carpal joints. Although degenerative joint disease has been reported to occur in multiple joints in elephants (Luikart & Stover 2005; Hoby *et al*. 2014), the carpal joints seem to be prone for these alterations. It was hypothesized that this is due to the unequal weight distribution between front and hind legs (Schmidt-Burbach 2009; Panagiotopoulou *et al*. 2012), the enormous forces acting in particular on the distal joints of the extremities (Steinmetz 2014), or to a correlation with the growth plate closure of the distal limb joints (Kaulfers *et a*l. 2010). Further research would be needed to investigate a corresponding relationship. According to the author's observations, a deformity in the direction of flexion represents an early stage of degenerative alterations in the carpal joint (Fig. 11). Moreover, affected elephants often showed an inwards rotation of both front legs (Fig. 6d).

Continuous monitoring of deformity development, ideally including photographic documentation, is recommended. These data may keep caring staff informed about the progress of joint disorders and enable timely implementation or adaptation of treatment. Radiographic imaging may represent another practical tool to diagnose and monitor joint deformities and severity of chondral degeneration. Although radiologic protocols for the elephant's limbs are available, a proper investigation of the more proximal joints can be complicated by the tissue masses surrounding them and the technique depends heavily on the training status of the elephant (Hittmair & Vielgrader 2000; Kaulfers *et al*. 2010).

4. Secondary traces

With increasing severity of the musculoskeletal disorder, the elephant will extend the amount of time spent in specific relieving positions (e.g. increased leaning rest vs. lying rest) (Schiffmann *et al*. 2018b). This change in behavioural patterns may lead to visually perceptible traces on the body of an elephant. The longer an elephant expresses relieving positions, the more extended secondary traces will be visible. To recognize them and figure out their etiopathogenesis, it is necessary to take an elephant's behaviour and interactions with specific structures of the environment into account. This should include day- as well as night-time behaviour and enclosures. Apart from skin alterations, a swelling on the tail base due to excessive leaning, and even traces on the tusks have been described (Schiffmann *et al*. 2018b). Furthermore, relieving positions as well as joint deformities lead to an uneven abrasion of the nails and pad. Depending on the specific conformation and pressure distribution, this will lead to a lack of wear and subsequent overgrowth of certain toenails (Fig. 12). At the same time other toenails may show signs of stress (e.g. recurrent cracks or chronic nail abscesses). Although continuous foot

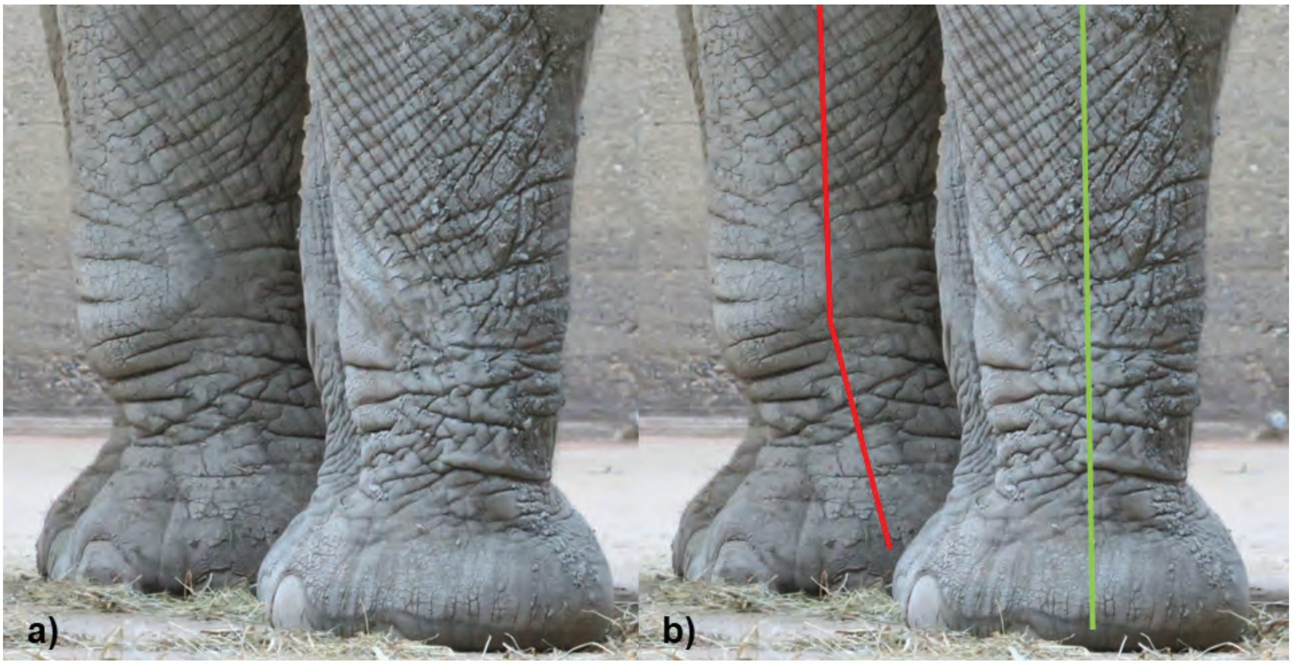

Figure 11. **(a)** Comparison of the carpal joint of a young-adult (22 years old) and a geriatric (46 years old) female African elephant standing right next to each other. **(b)** In the young-adult, the mechanical axis runs in a straight vertical line through the centre of the antebrachium, carpal joint and foot (green line). In contrast, there is a distinct angle of the mechanical axis in the carpal joint of the geriatric elephant (red line).

care will be required to control these alterations, they may persist as long as the underlying cause is not addressed and resolved (Luikart & Stover 2005).

5. Stiffness of gait and abnormal gait pattern

As mentioned above, obvious lameness is often missed in elephants even in cases of severe musculoskeletal disorders. Nevertheless, the continuous monitoring of an elephants' gait pattern, foot condition and activity level represents a critical part of musculoskeletal health assessment. The more familiar an observer will be with the individual gait pattern and activity level of an elephant, the quicker he will be aware of alterations therein. Video recordings and observation of gait patterns in slow motion might present an important tool and reveal subtle signs such as a shortening of the stride length.

Figure 12. Unevenly worn and overgrown toe nails in the front foot of a female African elephant suffering from post-mortem confirmed severe degenerative joint disease and deformities in her carpal joints (eg. Fig. 6a).

Conclusions

By continuously monitoring, assessing and documenting in a standardized manner all these aspects of an elephant's posture and behaviour, mahouts, elephant managers and veterinarians may be up to date of an individual's musculoskeletal health status. This will allow the timely implementation and adaptation of treatment. There is no doubt that visual and tactile examination has limitations compared to radiography and thermography (Miller *et al*. 2016). Further diagnostic tools to determine degenerative joint disease in elephants such as 3D radiographs and collagen biomarkers are being developed (Kilgallon *et a*l. 2015; Bentley *et al*. 2018). In contrast to these sophisticated techniques, the visual approach represents a cheap, non-invasive diagnostic tool, which can even be applied from a certain distance. The latter might be of relevance especially in less cooperative or aggressive elephants. In addition, continuous behavioural observations should be conducted directly or by a closed circuit television (CCTV) system. Furthermore, gait observations including slow motion video recordings should be considered in training programs for elephant keepers.

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