Morphological abnormalities in *Hyalomma dromedarii* and *Hyalomma rufipes* (Acari: Ixodidae) collected from dromedary camels (*Camelus dromedarius*) in Aswan, Egypt

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Abstract

The present study reports anomalies in *Hyalomma dromedarii* and *Hyalomma rufipes* adults collected from dromedary camels (*Camelus dromedarius*) in Aswan, Egypt, between January and June 2022. A total of 52 adult ticks displayed one or several local and/or general anomalies. A wide variety of local anomalies was observed including atrophy of one or multiple legs, ectromely, absence of accessory adanal and subanal plates, fusion of adanal and accessory plates, and presence of sclerotized formation in the ventral plate, as well as abnormalities of the spiracle, anal groove, festoon, parma, and posteromedian groove. General anomalies comprised of asymmetries and gynandromorphism. Local anomalies were documented among *H. dromedarii* and *H. rufipes*, whereas general anomalies were documented only from *H. dromedarii*. The present work represents the first report of deuteroedymander intrigue gynandromorphism in *H. dromedarii*, as well as the first report of morphological abnormalities in *H. dromedarii* and *H. rufipes* from Egypt.

Keywords Abnormalities · Gynandromorphism · *Hyalomma dromedarii* · *Hyalomma rufipes* · Ixodidae

Introduction

Morphological abnormalities in ticks have not been commonly reported, and the first case of anomalies in hard ticks was reported in 1899 (Neumann 1899). This phenomenon may be caused in nature by several extrinsic or intrinsic factors including host resistance to tick infestation, high temperature and humidity, environmental pollution, or somatic and germinal mutations (Latif et al. 1988; Dergousoff and Chilton 2007; Buczek et al. 2013, 2019;
Kar et al. 2015; Keskin et al. 2016; Shuaib et al. 2020). Additionally, exposure to acaricides and chemical agents may play a role too (Oliver and Delfin 1967; Buczek 2000). It is also possible that some of these factors may interact with gene regulatory networks during development to disrupt normal morphogenesis (Kittelmann et al. 2018); however, this requires further study.

Tick morphological abnormalities have been classified into general and local anomalies (Campana-Rouget 1959a, b). Gigantism, nanism, idiosomal constriction, duplication, gynandromorphism, and asymmetries are examples of general abnormalities, whereas extremely, atrophy of one or multiple legs, asymmetry of spiracles, and abnormality in festoons and ventral plates are among local anomalies (Campana-Rouget 1959a, b; Guglielmone et al. 1999; Kar et al. 2015; Shuaib et al. 2020; Laatamna et al. 2021). Gynandromorphism is a unique type of abnormality where morphological sex characteristics may be combined in a single specimen (Martini et al. 1999; Keskin et al. 2012). Additionally, gynandromorphic abnormalities can occur simultaneously with the other abnormalities mentioned above. There are five forms of gynandromorphism in ticks according to the classification of Campana-Rouget (1959a): bipartite protogynander, where the external features of both sexes are equally represented; deuterogynander, where features of one sex are decreased to a quadrant; metagynander, where features of one sex are decreased to a small segment; gynander intriqué, a protogynander or deuterogynander in which some features of one sex are embedded in areas of the opposite sex; and mosaic gynandromorphism, where there is no definitive line separating the male from the female. The bipartite protogynander is the most widely reported among these five forms (Labruna et al. 2002; Keskin et al. 2012).

Morphological abnormalities have been described in different genera of ixodid ticks including Amblyomma, Dermacentor, Haemaphysalis, Hyalomma, Ixodes, and Rhipicephalus (Campana-Rouget 1959a; Guglielmone et al. 1999; Zharkov et al. 2000; Alekseev et al. 2007; Kar et al. 2015; Keskin et al. 2016; Chitimia-Dobler et al. 2017; Wang et al. 2019). In the genus Hyalomma, anomalies have been reported in Hyalomma marginatum, Hyalomma aegyptium, Hyalomma scupense, Hyalomma impeltatum, Hyalomma excavatum, and H. dromedarii (Keskin et al. 2012, 2016; Nowak-Chmura 2012; Kar et al. 2015; Shuaib et al. 2020).

Numerous studies have reported abnormalities in several tick species in Europe, Asia, and America (Keskin et al. 2016; Larson and Paskewitz 2016; Ren et al. 2016; Chitimia-Dobler et al. 2017; Molaei and Little 2018, 2020; Chong et al. 2020; Molaei et al. 2020; Diyes and Rajakaruna 2021). In Africa, documentation of morphological abnormalities in ticks remains limited and has been reported only in South Africa, Uganda, Sudan, and Algeria (Gothe 1967; Balinandi et al. 2019; Shuaib et al. 2020; Laatamna et al. 2021). In this study, local and general morphological abnormalities were investigated among hard ticks collected from dromedary camels (Camelus dromedarius), for the first time from Egypt.

Materials and methods

Ticks were collected monthly from January to June 2022 from dromedary camels (n = 50) in a camel market in Aswan, Egypt (24.408642 N, 32.941018E). All tick specimens were removed from various parts of each camel’s body using fine forceps and then stored in vials containing 70% alcohol and 20% glycerol to be transported for morphological identification.
to the Acarology Laboratory, Department of Entomology, Ain Shams University. The collected specimens were identified based on morphological characters using identification keys (Hoogstraal 1956; Walker et al. 2003; Apanaskevich and Horak 2008; Apanaskevich et al. 2008; Okely et al. 2021). Ticks were identified and examined using a CZM4 Stereo Microscope (Labomed, Fremont, CA, USA) with an Am Scope LED-144 W-ZK white adjustable luminance and photographed using an attached MU1000 10MP microscopic camera (AmScope, Irvine, CA, USA). After the identification, ticks were deposited for future research in the Okely’s Tick Collection (Department of Entomology, Ain Shams University, Cairo, Egypt).

Results

In total, 1248 adult ticks were collected and morphologically identified and assigned to three genera (Amblyomma, Hyalomma, Rhipicephalus) and four species (Table 1). Of these, morphological abnormalities were observed in 52 (4.2%) specimens, only in H. dromedarii and H. rufipes species (Table 2). No abnormalities were noted in Amblyomma lepidum and Rhipicephalus pulchellus.

Local anomalies

Local morphological abnormalities in H. dromedarii were represented by atrophy of one or multiple legs, ectromely, absence of subanal plates, fusion of adanal and accessory adanal plates, presence of sclerotized formation in ventral plate, anomalies of subanal plates and adanal plates, spiracles, anal groove, festoons, and postmedian grooves, whereas local anomalies in H. rufipes were represented by atrophy of one leg, absence of accessory adanal plate and subanal plate, and an anomaly of adanal plate (Table 2).

Atrophy of legs was found in three male specimens (0.24%) of the total collected ticks. One H. rufipes male showed atrophy of the fourth right leg associated with idiosoma deformation on the same side (Fig. 1A, B). For the two H. dromedarii males, one showed atrophy of all legs on the right side, which was comparatively shorter than those on the left side (Fig. 1C, D), and the second specimen had atrophy of the fourth right leg (Fig. 1E). Ectromely of the first left leg of a H. dromedarii male was present and associated with deformation of the anterior part of the body on the same side (Fig. 1F, G).

Table 1  Hard ticks collected from dromedary camels from January to June 2022 in Aswan, Egypt

| Species collected       | Sex  | Number of ticks collected |
|------------------------|------|---------------------------|
| Hyalomma dromedarii    | Male | 1007                      |
|                        | Female | 218                      |
| Hyalomma rufipes       | Male | 8                         |
| Amblyomma lepidum      | Male | 13                        |
| Rhipicephalus pulchellus | Male | 2                         |
| Total                  |      | 1248                      |
Subanal plate anomalies were the most common local abnormality observed and were most prevalent in *H. dromedarii* males (n = 20, 38.5%) (Figs. 2 and 3). Fusion of adanal and accessory adanal plate was noted in one *H. dromedarii* male on the right side (Fig. 2A). Sclerotized formation of the ventral plate and an anomaly in anal groove form were both noted in one *H. dromedarii* male (Fig. 3D). Adanal plate anomalies were seen in 0.4% of the ticks, including four *H. dromedarii* males and one *H. rufipes* male (Figs. 3B and E and 4A, D, E). One *H. rufipes* male exhibited a missing right accessory adanal plate (Fig. 4A). Absent subanal plates were noted in two *H. dromedarii* males and one *H. rufipes* male (Fig. 4A–C).

Spiracle anomalies were observed in one female (Fig. 5C) and three males *H. dromedarii* (Fig. 5D–F). In the female specimen, the right spiracle showed unusual shape with dorsal prolongation sharply pointed and longer than normal (Fig. 5A, C). Two males had unusual shape of the left spiracle, which had dorsal prolongation slightly shorter than normal (Fig. 5D, E), and one male had the right spiracle with dorsal prolongation sharply pointed and shorter than normal (Fig. 5F). The ratios of spiracular plate length to dorsal prolongation in the three abnormal males were 1.3:1 (Fig. 5D), 1.6:1 (Fig. 5E), and 3:1 (Fig. 5F), whereas the ratio in the normal male was 1:1.5 (Fig. 5B).

### Table 2 Numbers of detected morphological abnormalities in *Hyalomma* tick species collected from January to June 2022 in Aswan, Egypt

| Type of abnormalities                          | Tick species   | n  | Rate of abnormal ticks (%) | Rate of examined ticks (%) |
|-----------------------------------------------|----------------|----|---------------------------|---------------------------|
| General                                       |                |    |                           |                           |
| Gynandromorphism                              | *H. dromedarii* | 1  | 1.9                       | 0.08                      |
| Asymmetries                                   | *H. dromedarii* (♂) | 2  | 3.8                       | 0.16                      |
| Local                                         |                |    |                           |                           |
| Atrophy of one or multiple legs               | *H. dromedarii* (♂) | 2  | 3.8                       | 0.16                      |
|                                                | *H. rufipes* (♂) | 1  | 1.9                       | 0.08                      |
| Ectromely of leg                              | *H. dromedarii* (♂) | 1  | 1.9                       | 0.08                      |
| Absence of accessory adanal plate             | *H. rufipes* (♂) | 1  | 1.9                       | 0.08                      |
| Absence of subanal plates                     | *H. dromedarii* (♂) | 2  | 3.8                       | 0.16                      |
|                                                | *H. rufipes* (♂) | 1  | 1.9                       | 0.08                      |
| Fusion of adanal and accessory adanal plates  | *H. dromedarii* (♂) | 1  | 1.9                       | 0.08                      |
| Presence of sclerotized formation in ventral plate | *H. dromedarii* (♂) | 1  | 1.9                       | 0.08                      |
| Subanal plate anomalies                        | *H. dromedarii* (♂) | 20 | 38.5                      | 1.6                       |
| Spiracle anomalies                             | *H. dromedarii* (♂) | 3  | 5.8                       | 0.24                      |
|                                                | *H. dromedarii* (♀) | 1  | 1.9                       | 0.08                      |
| Adanal plate anomalies                         | *H. dromedarii* (♂) | 4  | 7.7                       | 0.32                      |
|                                                | *H. rufipes* (♂) | 1  | 1.9                       | 0.08                      |
| Anal groove anomaly                            | *H. dromedarii* (♂) | 1  | 1.9                       | 0.08                      |
| Festoon anomalies                              | *H. dromedarii* (♀) | 4  | 7.7                       | 0.32                      |
| Parma anomalies                                | *H. dromedarii* (♂) | 3  | 5.8                       | 0.24                      |
| Postermedian groove anomalies                  | *H. dromedarii* (♂) | 2  | 3.8                       | 0.16                      |
| Total                                         |                | 52 | 100                       | 4.16                      |

n = number of anomalous ticks
Fig. 1  Atrophy of leg in *Hyalomma rufipes* male, dorsal view (A), ventral view (B); atrophy of legs in *H. dromedarii* male, dorsal view (C), ventral view (D, E); ectromely in *H. dromedarii* male, dorsal view (F), ventral view (G).
Fig. 2 Subanal plate anomalies in *Hyalomma dromedarii* male, ventral view (A–L); fusion of adanal and accessory adanal plate in *H. dromedarii* male, ventral view (A)
Fig. 3. Sub-anal plate anomalies in Hyalomma dromedarii male, ventral view (A–H); adanal plate anomaly in *H. dromedarii* male, ventral view (B, E); sclerotized formation in ventral plate and anal groove anomaly on *H. dromedarii* male, ventral view (D).
Fig. 4 Missing subanal and accessory adanal plates in *Hyalomma rufipes* male, ventral view (A); missing subanal plates in *H. dromedarii* male, ventral view (B, C); adanal plate anomalies in *H. dromedarii* male, ventral view (D, E).

Fig. 5 Spiracles of *Hyalomma dromedarii*, normal female (A); normal male (B); abnormal female (C); abnormal males (D–F).
Fusion of festoons was observed in three *H. dromedarii* males (Fig. 6E, G, H), whereas one *H. dromedarii* male exhibited 10 festoons around the parma (Fig. 6I). Furthermore, parma anomalies were noted in three *H. dromedarii* males (Fig. 6E, G, I). One *H. dromedarii* male exhibited an abnormal shape of postmedian groove and exoskeleton anomaly (Fig. 6F), and another *H. dromedarii* male showed postmedian groove not reaching parma (Fig. 6I).

**General anomalies**

Asymmetry was observed in 3.8% (*n*=2) of *H. dromedarii*. The *H. dromedarii* males showed slight asymmetry on the right side (Fig. 6A–D), whereas in one (Fig. 6B, D) asymmetry was also associated with local anomaly (subanal plate anomalies) (Fig. 3H).

Gynandromorphism was observed in one specimen of *H. dromedarii* (Figs. 7 and 8). This gynandromorphic specimen had the size of a female (8.4 mm long), and the ratio of scutum length-to-width is 0.82:1 (Fig. 7A), whereas the length of male specimens usually did not exceed 8.3 mm. Capitulum on dorsal view showed the features of a female, with oval porose areas in basis capitulum and the three segments of palps (segment II longer than segments I and III, also the apex of segment III broadly rounded) displayed female features (Fig. 7B). The right spiracle displayed female features (Fig. 7C), whereas the left one had an abnormal shape for both sexes (Fig. 7D). The genital aperture had abnormal shape for both sexes; however, the coxae showed the features of a female (Fig. 7E). Ventral male features were observed in ventral plates: one adanal, one subanal, and one accessory adanal plates were present on the left side only (Fig. 7F). Female features were generally present dorsally, but with pieces of male conscutum embedded in the female alloscutum (Fig. 8A). The specimen displayed male features on the dorsal left side, with the presence of a posterior ridge, well-defined paramedian groove, and short lateral groove. Moreover, left dorsal festoons were of a typical shape for males (Fig. 8B). The number of female characters in the gynandromorphic specimen was more than eight, whereas the male characters were only three. So, the gynandromorphic specimen looks like a female at first view, due to the dominance of female morphological characters.

**Discussion**

In this study, we report morphological abnormalities in 4.2% of total ticks collected from dromedary camels in Aswan, Egypt. Our findings are in agreement with previous studies (Labruna et al. 2000; Alekseev et al. 2007; Keskin et al. 2016; Chitimia-Dobler et al. 2017; Azzi et al. 2019; Salceda-Sanchez et al. 2020), which indicated morphological anomalies occur in a range of 1 to 48% among ixodid tick populations. However, these results are not in accord with other studies that reported morphological anomalies in 0.03–0.62% of ixodid tick populations (Latif et al. 1988; Guglielmone et al. 1999; Dergousoff and Chilton 2007; Nowak-Chmura 2012; Kar et al. 2015; Chitimia-Dobler and Pfeffer 2017; Munoz-Leal et al. 2018; Balinandi et al. 2019; Molaei and Little 2020; Shuaib et al. 2020; Laatamna et al. 2021). The anomaly prevalence is different from study to study according to the tick species and number of investigated ticks. Ticks with anomalies are found during studies, which do not have tick anomalies in focus, therefore, it is important to be observed
Fig. 6 Asymmetries in *Hyalomma dromedarii* male, dorsal view (A, B), ventral view (C, D); festoon anomalies in *H. dromedarii* male, dorsal view (E, G–I); parma anomalies in *H. dromedarii* male, dorsal view (E, G, I); postmedian groove anomalies in *H. dromedarii* male, dorsal view (F, I)
Fig. 7 Gynandromorphism in *Hyalomma dromedarii*, dorsal view (A); capitulum dorsal view (B); normal shape of female right spiracle (C); abnormal shape of left spiracle for both sexes (D); abnormal shape of the genital aperture and coxae with female features (E); the male characters on the left side with the presence of the ventral plates, ventral view (F)
Fig. 8 Gynandromorphic *Hyalomma dromedarii* with the pieces of male scutum (marked with white arrows) embedded in female alloscutum, dorsal view (A); the male characters on the left side with the presence of a posterior ridge, paramedian groove, and lateral groove, dorsal view (B)
and described. Although several tick surveillance programs have been implemented in various ecological zones throughout the country (Okely et al. 2022), this is the first report on morphological abnormalities in ticks from Egypt.

Leg atrophy was reported in several genera of hard ticks such as *Dermacentor*, *Ixodes*, *Rhipicephalus*, *Amblyomma*, and *Hyalomma* (Nowak-Chmura 2012; Kar et al. 2015; Chitimia-Dobler et al. 2017; Chitimia-Dobler and Pfeffer 2017). Previous studies have documented atrophy of legs in *Hyalomma* species such as *H. impeltatum* (Shuaib et al. 2020), *H. marginatum* (Kar et al. 2015; Keskin et al. 2016), and *H. scupense* (Kar et al. 2015); however, no previous cases of such abnormalities have been documented in *H. dromedarii* and *H. rufipes*.

Ectromely is described in a *H. dromedarii* male during this study. This anomaly has been recorded previously in *H. marginatum* in nature (Buczek et al. 1991) and was also observed in *H. marginatum* larvae experimentally exposed to 90% RH and 25 °C, kept under these conditions during the whole embryonic development (Buczek 2000). Ectromely was also detected in other species such as *Amblyomma cajennense*, *Amblyomma neumanni*, *Amblyomma americanum*, *A. lepidum*, *Dermacentor andersoni*, *Ixodes scapularis*, *Rhipicephalus decoloratus*, *Rhipicephalus sanguineus*, *Rhipicephalus microplus*, and *Rhipicephalus evertsi evertsi* (Guglielmone et al. 1999; Dergousoff and Chilton 2007; Balinnandi et al. 2019; Molaei et al. 2020; Shuaib et al. 2020). This study describes for the first time ectromely in a *H. dromedarii* male.

Ventral plate anomalies among *Hyalomma* species were documented in *H. dromedarii* and *H. impeltatum* as missing subanal plates and atrophy of adanal and accessory adanal plates (Shuaib et al. 2020). Notably, we observed one *H. rufipes* male with missing accessory adanal plate and subanal plate. Also, the same specimen displayed anomaly in adanal plate form. To our knowledge, this is the first report of ventral plate anomalies in *H. rufipes*. In addition, several other anomalies were observed in *H. dromedarii* males including fusion of adanal and accessory adanal plates on one side of the body, missing subanal plates, and anomalies in adanal and subanal plate forms. Ventral plate anomalies were detected for the first time in male *H. dromedarii* specimens from Egypt during this study.

Anal groove anomalies were documented in an *Amblyomma latum* male collected from exotic reptiles in Poland (Nowak-Chmura 2012) and *Ixodes ricinus* females and nymphs collected by the flagging method in Germany (Chitimia-Dobler et al. 2017), but no previous studies have reported such anomalies in *Hyalomma* species. Sclerotized formation in the ventral plate was observed in one *H. dromedarii* male in our study and in the same species reported earlier from Sudan (Shuaib et al. 2020). In addition, anomalies of the dorsal prolongation of spiracles were seen in one female and three *H. dromedarii* males. Various types of anomalies of spiracles have been reported, such as atrophy or lack of one spiracle in *H. aegyptium* and *H. excavatum* (Keskin et al. 2016). Spiracular abnormalities have also been described in *Amblyomma hebraeum*, *Amblyomma longirostre*, *H. scupense*, *H. marginatum*, and *Rhipicephalus turanicus* (Campana-Rouget 1959b; Kar et al. 2015).

Fusion of festoons was detected in three specimens of *H. dromedarii*, but there is no such previous report for this species. However, this case was observed in *H. marginatum* (Keskin et al. 2016). Posterior median groove and parma anomalies are reported during this study in *Hyalomma* species.

Asymmetries of the idiosoma were observed in several ixodid ticks such as *Amblyomma parvum*, *Amblyomma tigrinum*, *A. cajennense*, *A. neumanni*, *A. latum*, *A. lepidum*, *Haemaphysalis parva*, *H. marginatum*, *H. scupense*, *H. excavatum*, *I. ricinus*, *Rhipicephalus bursa*, *R. decoloratus*, and *R. evertsi evertsi* (Buczek et al. 1991; Guglielmone et al. 1999; Nowak-Chmura 2012; Kar et al. 2015; Keskin et al. 2016; Chitimia-Dobler et al. 2017;
Shuaib et al. 2020). These cases occur in nature due to many factors, including – but not limited to – missing tissues, underdevelopment of structures and organs in the idiosoma, or abnormal development during metamorphosis from the immature stages to the adult (Kar et al. 2015). Additionally, these factors may result in the formation of other types of abnormalities beyond idiosomal asymmetries. Two cases of asymmetry in the idiosoma are detected in H. dromedarii males in Egypt during this study.

Gynandromorphism has been documented in approximately 80 field-collected specimens of ixodid ticks (Salceda-Sánchez et al. 2020), and the frequency of gynandromorphism in Amblyomma and Hyalomma species is relatively higher (Labruna et al. 2002; Keskin et al. 2012; Muñoz-Leal et al. 2018). No previous reports of gynandromorphism were made in H. dromedarii collected from a dromedary camel. According to the classification system for tick gynandromorphs reported by Campana-Rouget (1959a), the gynandromorphic specimen of this study is considered a deuterogynander intrigue, where characters of male parts are reduced to a quadrant. Several cases of gynandromorphism in Hyalomma species have been described in H. marginatum (Keskin et al. 2012, 2016; Buczek et al. 2014; Kar et al. 2015), Hyalomma asiaticum (Chen et al. 2015), Hyalomma truncatum (Kostrzewski et al. 1986; Clarke and Rechav 1993), Hyalomma anatolicum (Kumar and Nagar 1979), and Hyalomma savignyi (Feldman-Muhsam 1950). However, the deuterogynander type has only been previously documented in H. truncatum infesting rabbits in the laboratory (Clarke and Rechav 1993). The deuterogynander gynandromorphic type has also been described for Rhipecephalus sanguineus sensu lato and Rhipicephalus simus (=praetextatus) (Campana-Rouget 1959a, b; Salceda-Sánchez et al. 2020; Ortíz-Giraldo et al. 2022). This study documents gynandromorphism in ixodid ticks from Egypt.

These anomalies might be due to climatic conditions like high temperature and dry weather, as Aswan is one of the hottest and driest cities in the whole world (https://weatherspark.com/). It has a hot dry desert, and it suffers from thermal stress throughout the whole year (El Menshawy et al. 2022). Climate change influences could probably increase the prevalence of morphological anomalies in structures of ticks (Nowak-Chmura 2012; Kar et al. 2015; Shuaib et al. 2020), so studies of the environmental factors under changing climate that may have led to these phenomena in Egypt are important.

In conclusion, the present study reports several types of morphological abnormalities in H. dromedarii and H. rufipes collected from dromedary camels in Egypt. It is recommended to intensify field surveillance programs for collecting tick specimens from different ecological zones in Egypt and monitoring anomalies in ticks from different hosts and zones.

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Author contributions MO, LCD, and DKB contributed to the study conception and design. MO conducted tick collection, morphological identification, provided figures, and wrote the first draft of the manuscript. LCD and DKB read, edited, and reviewed the manuscript. All authors approved the final manuscript.

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