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RESEARCH ARTICLE

Prevalence of Enteric Parasites in Pet Macaques in Sulawesi, Indonesia

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On the Indonesian island of Sulawesi, nonhuman primate pets come into frequent contact with humans, presenting the possibility of zoonotic and anthropozoonotic disease transmission. We collected fecal samples from 88 pet macaques representing six of the seven macaque species currently recognized as endemic to Sulawesi (*Macaca nigra*, *M. nigrescens*, *M. hecki*, *M. tonkeana*, *M. maura*, and *M. ochreata*) as well as two non-endemic species (*M. fascicularis* and *M. nemestrina*) in order to determine the prevalence of intestinal parasitic infection in this population. Seven taxa of intestinal protozoa (*Blastocystis hominis*, *Iodamoeba bütschlii*, *Entamoeba coli*, *Entamoeba hartmanni*, *Chilomastrix mesnili*, *Endolimax nana*, and *Retortamonas intestinalis*) and three taxa of nematodes (hookworm, *Trichuris* spp., and *Ascaris* spp.) were detected. The overall parasitization rate was 59.1%. Commensal organisms predominated in this population. Parasitization was not statistically correlated with macaque age group, sex, species, or location, or with the owner's level of education. These findings are discussed in the context of primate pet ownership practices in Sulawesi. Am. J. Primatol. 62:71–82, 2004. © 2004 Wiley-Liss, Inc.

Key words: Sulawesi; pet primates; *Macaca*; intestinal parasites; protozoa; nematodes; zoonoses

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INTRODUCTION

The morphological, physiological, behavioral, and genetic similarities between humans and nonhuman primates contribute to their susceptibility to a similar spectrum of pathogens [Brack, 1987]. This shared susceptibility enables zoonotic (nonhuman primate to human) and anthropozoonotic (human to nonhuman primate) transmission of infectious agents to occur in situations where humans come into contact with nonhuman primates. The cross-species transmission of infectious agents poses a potential threat to both primates and humans.

Ownership of pet primates is a common practice in source countries that contain wild primate populations [Jones-Engel et al., 2002; McCann & Taylor, 2002; Fitch-Snyder et al., 2002; Abernathy et al., 2002]. In countries such as Indonesia, the destruction of primate habitats, bushmeat-hunting, and trapping as a means of eliminating crop-raiding lead to the acquisition of nonhuman primates (most often infants and juveniles) that become pets. Although no complete census data on pet primates in Sulawesi are available, the conditions and practices that can result in the acquisition of pets are on the rise [Jones-Engel et al., in press]. Since pet primates live in constant and close proximity to humans, there is the possibility of cross-species transmission of infectious agents in this context; however, it is yet to be well studied [Jones-Engel et al., 2001].

Prior research on infectious diseases in pet primates has included work on leprosy, [Hagstad, 1983], SIV [Georges-Courbot et al., 1998], and enteric bacteria [Fox, 1975; Tresierra-Ayala & Fernandez, 1997]. Zoonotic transmission of enteric parasites from domestic animals, such as cats, dogs, and cattle, is a well-described phenomenon [Stehr-Green et al., 1987; Harvey et al., 1991; Olson et al., 1997; Fok et al., 2001; Mazyad & El-Nemr, 2002]. To date, however, enteric parasitization among pet primates has not been well studied. The present cross-sectional study takes a first step toward learning about transmission of enteric parasites between humans and pet primates on Sulawesi. Our aim was to characterize the prevalence of intestinal fauna in pet primates in order to determine whether the parasitic fauna of pet primates pose an infectious threat to human populations.

MATERIALS AND METHODS

Pet Macaques on Sulawesi

Sulawesi is home to at least seven morphologically distinct species of macaque [Fooden, 1969]. Each species occupies a distinct range, with hybrid populations occurring naturally in areas of sympatry [Bynum et al., 1999; Evans et al., 2001; Froehlich & Supriatna, 1996; Groves, 1980; Watanabe et al., 1991]. Previous research suggests that on Sulawesi, primate pets are acquired through trapping and as a by-product of hunting and crop protection (Jones-Engel, unpublished data). Macaque species not native to Sulawesi also make up part of the pet population. Most of these non-native primates are acquired on other Indonesian islands and accompany their owners when the owners move. Generally, infants and juveniles are considered most desirable as pets because macaques often become aggressive as they reach sexual maturity. Primate-pet owners frequently sell or give away their pets as the animals mature.

Data Collection and Analysis

Fecal samples from 88 pet macaques were collected during two field seasons (June–August 2000, and May 2001) on the northern, east-central, and southern

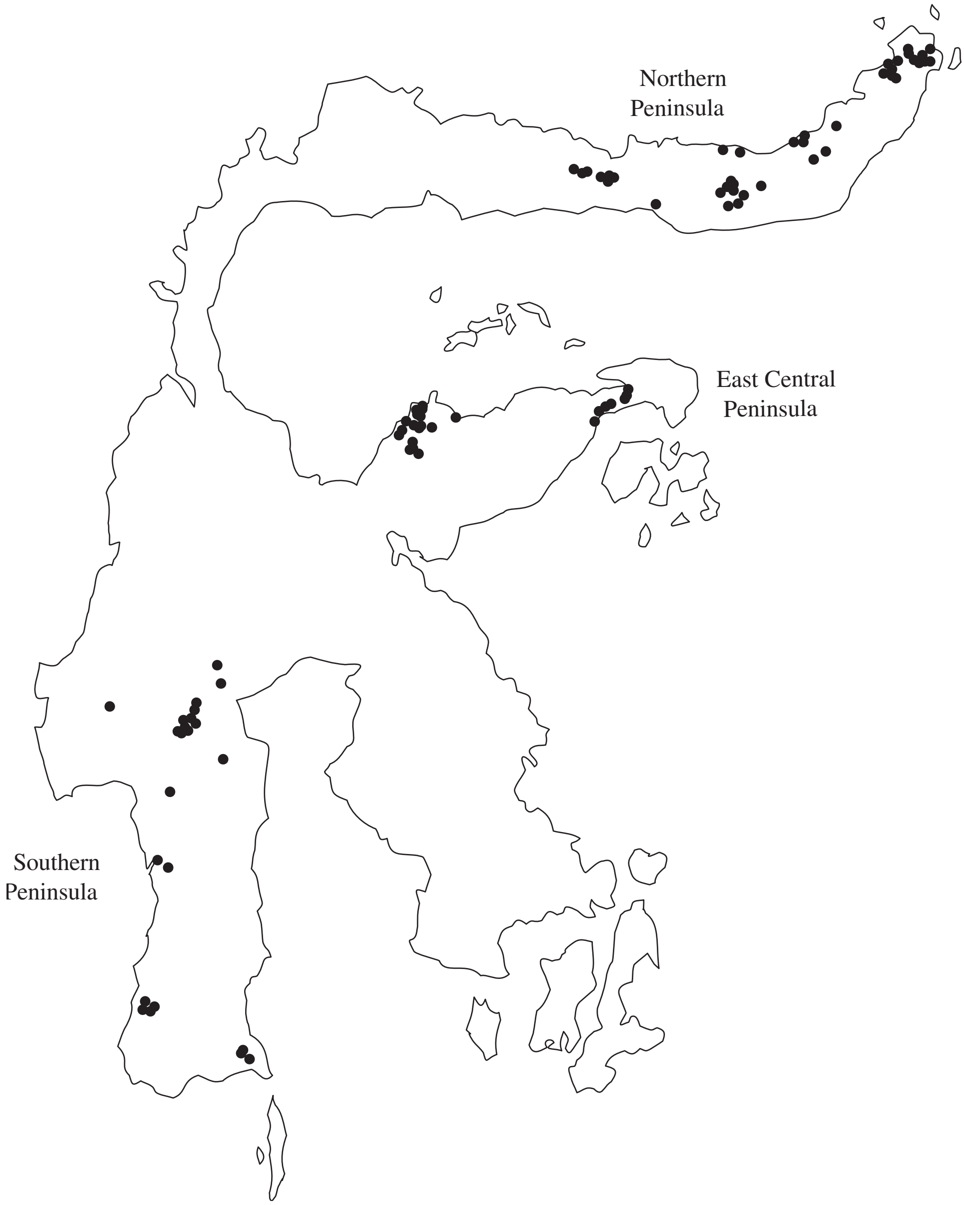

Fig. 1. Map of Sulawesi. The dots represent the locations of the study animals.

peninsulas of the Indonesian island of Sulawesi. Figure 1 shows the geographic distribution of the macaques sampled in this study.

Study subjects were located by traveling from village to village along the island's main roads and inquiring about the presence of pet primates. After written consent was obtained, a questionnaire was administered to the pet owner in Bahasa Indonesia, the national language. The survey was designed to focus on the contexts of primate pet ownership, and to develop a demographic profile of pet owners in Sulawesi. It also sought other information bearing on human–primate contact and disease transmission, including how and where pets were obtained, who was responsible for the care of the pet, whether or not the pet had ever been ill, and the fate of any previous pets. The demographic data elicited included the owner's age, sex, religion, ethnicity, education, occupation, and marital status. Health information relating to bite or scratch wounds inflicted by nonhuman primates was also collected.

The pets were anesthetized with 3 mg/kg of Telazol® (tiletamine and zolazepam; Fort Dodge Laboratories; Fort Dodge, IA) intramuscularly, and fecal samples were acquired by a fecal loop inserted into the rectum, or by free-collection. The fecal samples were immediately placed in Ecofix Para-Pak®; Fort Dodge Laboratories; Fort Dodge, IA and kept at ambient temperature until they were analyzed. Ecofix Para-Pak® is a one-vial system for the routine collection, transportation, preservation, and examination of fecal specimens for intestinal parasites, which preserves both cystic and amoebic forms of protozoa as well as the larva and eggs of worms. The vial contains 15 ml of Ecofix®, which is a proprietary, ecologically safe fixative that contains no formalin or mercury salts. Samples collected by this protocol are suitable for direct examination, concentration, and permanent staining with trichrome and iron hematoxylin stains.

All fecal specimen analysis was performed by a trained parasitologist at the Esoterix Simian Diagnostic Laboratory (San Antonio, TX), who processed them using a ''SpinCon,'' a unique double-filtration conical tube that is patented for the concentration of parasite eggs, larvae, and protozoa from fecal specimens. The SpinCon involves passing a surfactant-treated, preserved stool specimen through a preliminary screen by gravity flow. The specimen is then forced by centrifugation (2,500 rpm for 10 min) through a series of two screens with successively finer mesh. The supernatant is then decanted and the remaining concentration is subjected to a direct microscopic technique, as well as a smear for trichrome and acid-fast staining. Microscopic examination is performed with 100× and 400× objective lenses. The trichrome and acid-fast smears are scanned with a 1000× oil immersion lens.

Dental eruption sequences were used to estimate macaque age [Sirianni & Swindler, 1985]. A pet primate's species was determined based on morphological and pelage characteristics as previously described by Fooden [1969].

Statistical Analysis

Formal comparisons of parasite prevalence among population subgroups were conducted with the JMP-IN 4 statistical software package (version 4; SAS Institute, Inc., Cary, NC). Chi-square tests contained in the SPSS statistics software package (release 11.0.1; Chicago, IL) were used to test for statistical significance of differences in parasite prevalence among population subgroups. The statistical significance of differences in the average number of parasite taxa between subgroups was calculated by analysis of variance (ANOVA; also contained in SPSS).

RESULTS

Study Population

Table I summarizes the demographic characteristics of the study animals. Fecal samples from 88 macaques were analyzed. The study animals included six of Sulawesi's seven currently recognized macaque species (*Macaca nigra*, *M. nigrescens*, *M. hecki*, *M. tonkeana*, *M. maura*, and *M. ochreata*), as well as two

TABLE I. Demographic Profile of the Study Sample

Age-sex class	*Macaca nigra*	*Macaca nigrescens*	*Macaca hecki*	*Macaca tonkeana*	*Macaca maura*	*Macaca ochreata*	*Macaca fascicularis*	*Macaca nemestrina*	*Macaca hybrid*	Total
AM[a]	3	0	0	2	2	0	1	0	0	**8**
SAM[b]	2	1	0	4	1	0	0	0	2	**10**
JM[c]	4	5	4	9	2	1	2	0	2	**29**
Subtotal males	**9**	**6**	**4**	**15**	**5**	**1**	**3**	**0**	**4**	**47**
AF[d]	3	1	0	3	0	0	1	0	3	**11**
SAF[e]	1	0	0	2	0	0	1	1	2	**7**
JF[f]	5	1	0	7	3	0	0	0	7	**23**
Subtotal females	**9**	**2**	**0**	**12**	**3**	**0**	**2**	**1**	**12**	**41**
Total[g]	**18**	**8**	**4**	**27**	**8**	**1**	**5**	**1**	**16**	**88**
Geolocation										
N Pen[h]	18	8	4	0	0	0	2	0	8	**40**
E-C Pen[i]	0	0	0	18	0	0	0	0	6	**24**
S Pen[j]	0	0	0	9	8	1	3	1	2	**24**

[a]Adult males.
[b]Subadult males.
[c]Juvenile males.
[d]Adult females.
[e]Subadult females.
[f]Juvenile females.
[g]Sum of all males and females.
[h]Northern peninsula.
[i]East-central peninsula.
[j]Southern peninsula.

non-native species (*M. fascicularis* and *M. nemestrina*) that were brought to Sulawesi from other Indonesian islands. Sixteen of the animals studied were hybrids of Sulawesi species.

Juvenile macaques (defined as individuals between 1 and 3 years of age) predominated in the study population (n = 52; 59%). The absence of infants in this sample may be explained by anecdotal reports of high mortality among very young pet macaques in Sulawesi; however, the mortality rates of infant pets have not been measured. Subadults (n = 17; 19%) and adults (n = 19; 22%) may be relatively underrepresented (compared to wild populations) among pets in Sulawesi because owners frequently give them away or sell them at these ages.

Prevalence of Enteric Parasites

Ten taxa (seven protozoan taxa and three nematode taxa) of enteric parasites were encountered in this study sample. The most frequently encountered protozoa were *Blastocystis hominis* (present in 43% of macaques), *Iodamoeba bütschlii* (present in 22%), and *Entamoeba coli* (present in 14%). The nematodes hookworm, *Trichuris spp*., and *Ascaris* were found in fecal samples from 6%, 3%, and 1%, respectively, of the pet macaques in this study. Table II presents prevalence data for the parasites found in each species of macaque.

Table III presents data on the prevalence of parasitization (which is defined as the percentage of animals infected with at least one parasite) and the average number of parasite taxa per individual. Prevalence is tabulated by species, sex, and age group.

Parasite prevalence was higher among the northern-peninsula macaques (73%) than among macaques from the east-central (54%) and southern (42%) peninsulas. A comparison of mean prevalence in the three geographic areas by one-way ANOVA showed a significant effect ($F\ (2,87) = 3.23$, $P = 0.04$). A post-hoc Tukey test revealed that the difference in parasite prevalence between the northern and southern peninsulas was the source of the effect ($P = .04$). No geographic differences in prevalence were observed for the individual parasites. No statistical differences in parasitization were detected for sex, age, species, owner education, or pet location. Similarly, a comparison of the prevalence of individual parasite taxa among sample subgroups revealed no statistically significant correlations.

Pets without parasites in their feces accounted for 40.9% of the study population, those with one parasite taxon represented 34.1% of the study population, and those with two parasite taxa accounted for 15.9% of the total. Three or four parasite taxa were detected in the feces of less than 10% of the pets. There were no statistically significant correlations between the number of parasite taxa detected per individual and sex, age class, species, or geolocation. Tests for correlation between individual parasites were run for those pets that tested positive for two or more parasites. The results showed no significant relationships, with one exception: the presence of *B. hominis* was negatively correlated with that of hookworm ($r(22) = -.50$, $P = .02$).

DISCUSSION

Taxa of Enteric Parasites Identified

Microscopic analysis detected 10 distinct taxa of enteric parasites, a faunal diversity consistent with previously published data from populations of wild [Abbot & Majeed, 1984; Appleton & Boinski, 1991; Appleton et al., 1994; Collet

Table II. Prevalence of Parasites by Macaque Species

Pathogen	*M. nigra*	*M. nigrescens*	*M. hecki*	*M. tonkeana*	*M. maura*	*M. ochreata*	*M fascicularis*	*M. nemestrina*	*Macaca* hybrid	Total (n=88)
Entamoeba coli	2/18	1/8	1/4	2/27	1/8	1/1	1/5	0/1	3/16	12/88
Blastocystis hominis	8/18	5/8	4/4	8/27	3/8	1/1	1/5	1/1	7/16	38/88
Iodamoeba bütschlii	5/18	1/8	1/4	2/27	3/8	1/1	0/5	0/1	6/16	19/88
Entamoeba hartmanni	2/18	0/8	0/4	0/27	0/8	0/1	0/5	0/1	0/16	2/88
Endolimax nana	1/18	0/8	0/4	0/27	0/8	0/1	0/5	0/1	0/16	1/88
Chilomastrix mesnili	0/18	1/8	1/4	0/27	0/8	0/1	0/5	0/1	0/16	2/88
Retortamonas intestinalis	0/18	0/8	1/4	0/27	0/8	0/1	0/5	0/1	0/16	1/88
Ascaris spp.	1/18	0/8	0/4	0/27	0/8	0/1	0/5	0/1	0/16	1/88
Trichuris spp.	0/18	0/8	1/4	1/27	1/8	0/1	0/5	0/1	0/16	3/88
Hookworm	1/18	0/8	0/4	2/27	0/8	0/1	0/5	0/1	2/16	5/88

TABLE III. Number of Animals Parasitized by at Least One Parasite and Average Parasite Taxa Per Individual Broken Down by Species, Sex, and Age Group

Category	n	% animals parasitized	Mean parasite taxa/individual (SD)
Species			
M. nigra	18	72.2 (13/18)	1.1 (1.1)
M. nigrescens	8	62.5 (5/8)	1.0 (1.1)
M. hecki	4	100.0 (4/4)	2.3 (1.3)
M. tonkeana	27	40.7 (11/27)	0.6 (0.8)
M. maura	8	62.5 (5/8)	1.0 (1.1)
M. ochreata	1	100.0 (1/1)	3.0 (n/a)
M. fascicularis	5	20.0 (1/5)	0.4 (0.9)
M. nemestrina	1	100.0 (1/1)	1.0 (n/a)
M. sp. Hybrids	16	58.8 (11/16)	1.1 (0.96)
Males	47	59.6 (28/47)	1.0 (0.9)
Females	41	58.5 (24/41)	1.0 (1.1)
Juveniles	52	63.5 (33/52)	1.1 (1.1)
Subadult	17	58.8 (10/17)	0.8 (0.8)
Adult	19	47.4 (9/19)	0.7 (0.8)
Total	88	59.1% (52/88)	0.9 (1.0)

et al., 1986; Ghandour et al., 1995; Gotoh, 2000; Gotoh et al., 2001; Kessler et al., 1984; Langsoud-Soukate et al., 1995; Müller-Graf et al., 1996; Muriuki et al., 1998; Toft, 1982; Ashford et al., 1990] and captive [Collet et al., 1986; Gotoh et al., 2001; Tachibana et al., 2001; Toft, 1982; Gomez et al., 1996] primates. All of the taxa identified in the study population had been documented in both wild primate populations and human populations [Ghandour et al., 1995; Hasegawa et al., 1992; Kersten et al., 2002; Mangali et al., 1993; Salim et al., 1999; Widjana & Sutisna, 2000] by previous authors. The overall prevalence of parasitization (the percentage of subjects that tested positive for at least one parasite) was 59.1%, which is within the broad range described in previously published data from wild and captive primate populations.

A comparison of the enteric nematode fauna identified in the present study to that found in prior studies of human and wild macaque populations in Sulawesi revealed more commonalties between human and pet populations than between pet and wild populations of Sulawesi macaques. Specifically, two surveys of human populations from Sulawesi found five nematode taxa–three of which (*Trichuris*, *Ascaris*, and hookworm) were found in our study population [Hasegawa et al., 1992; Mangali et al., 1993]. In contrast, six parasitic nematode taxa were found in a survey of wild macaques (*M. hecki* and *M. hecki*/*M. tonkeana* hybrids) in northern Sulawesi, only one of which (*Trichuris*) was encountered in our study population [Gotoh et al., 2001]. No data on enteric protozoan fauna are available for wild Sulawesi macaques; however, the studies by Hasegawa et al. [1992] and Mangali et al. [1993] encountered eight protozoan taxa in human populations, six of which we detected in our pet study population. Only *Retortamonas intestinalis*, which was detected in a single pet, was not shown in the above human studies. Taken together, these data suggest that the intestinal fauna of pets in this study parallels that of autochthonous human populations.

Pet Primates—A Unique Population

These findings should be regarded in the context of what we know about pet primate ownership in Sulawesi. Our data indicate that most pet macaques in Sulawesi are acquired as young animals (usually juveniles or infants) [Jones-Engel et al., in press]. As a result, these animals may be removed from their natural groups before they are exposed to most of the parasites enzootic in those groups. When they subsequently become pets, their exposure to parasites is largely, if not wholly, determined by their human-shaped environment (i.e., where they are kept, their water and food supply, and contact with other domesticated animals). Hence, their intestinal fauna might be expected to resemble that of the surrounding human populations.

Pet primates thus constitute a unique population of primates with unique epizootiological considerations. Unlike wild primates, they live in constant, close proximity to humans. Unlike most zoo primates, they have little if any have contact with other primates (although there are accounts of pets being courted by wild primates). Unlike the situation with laboratory primates, contact with humans is unregulated, and transmission of infection is undeterred by gloves, masks, or other protective measures designed to protect both humans and primates from pathogen transmission. Furthermore, and also in contrast to laboratory primates, the health of pets in habitat countries is generally not monitored and maintained by veterinary medical professionals who are capable of diagnosing and treating intestinal infections.

Paucity of Pathogenic Parasites

It is interesting to note that in this primate sample the three most commonly encountered parasite taxa (*Blastocystis hominis*, *Iodamoeba bütschlii*, and *Entamoeba coli*, occurring in 43%, 21%, and 14% of macaques, respectively) are generally regarded as minimally pathogenic or nonpathogenic in both human and nonhuman primates. Of the parasitic taxa encountered in this study, only the nematode taxa hookworm, *Trichuris*, and *Ascaris* (found in 6%, 3%, and 1% of the subjects, respectively) are considered significant pathogens. This paucity of pathogenic fauna contrasts with data from wild primate populations [Abbot & Majeed, 1984; Appleton & Boinski, 1991; Appleton et al., 1994; Collet et al., 1986; Ghandour et al., 1995; Gotoh, 2000; Gotoh et al., 2001; Kessler et al., 1984; Langsoud-Soukate et al., 1995; Müller-Graf et al., 1996; Muriuki et al., 1998; Toft, 1982; Ashford et al., 1990], which show higher infection rates with pathogens, including *Balantidium coli*, *Entamoeba histolytica*, *Giardia lamblia*, hookworm, *Trichuris*, and *Strongyloides*. One possible explanation for this observation is that mobility may play an important role in the acquisition of enteric parasites. By virtue of their ability to travel, humans and wild macaques may have more frequent contact with intestinal parasites and hence a higher incidence of infection than pets, which are usually tethered in a fixed location. Also, since antiparasitic drugs are readily available in Sulawesi, and people infected with pathogenic parasites would be expected to use antiparasitic medications more frequently than those infected only with commensals, pets may be exposed to pathogenic parasites less frequently than commensals. An alternate explanation for the lack of pathogenic fauna in these pets is that infection causes significant mortality in pets.

Future Work

The present study provides a preliminary glimpse of enteric parasitic infections among pet primates in a source country, and points the way to further research. Data on the prevalence of pet ownership are needed to better define the scope of the phenomenon. Research comparing parasite loads among pets and owners would help to clarify the epidemiology and epizootiology of zoonotic and anthropozoonotic transmission in this context. Ideally, such data would be collected and correlated with more complete data on the human environment-—especially as regards the water supply, sanitation, and the presence of other domesticated animals.

CONCLUSIONS

Humans and nonhuman primates share a susceptibility to a wide range of fecal parasites. In Sulawesi, primate-pet ownership provides a context for the cross-species transmission of pathogens. Our data suggest that infection with enteric parasites is common in pet macaques on Sulawesi, but that relatively few of these infections are caused by pathogenic organisms. The intestinal fauna detected in this population parallels that detected in previously published analyses of human populations in Sulawesi. These observations may be explained by the unique circumstances relating to pet macaques and their environment in Sulawesi.

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