# Salmonella enterica serovar Panama meningitis in exclusive breastfeeding infants

# Report of 4 cases, clinical features and therapeutic challenges

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### Abstract

Rationale: The pathway of Nontyphoid Salmonella meningitis, especially in exclusive breastfeeding infants, has not been well characterized.

Patient concerns: We analyzed data related to nontyphoid Salmonella meningitis in 4 infants.

Diagnoses: No diarrhea was observed and the coproculture was negative for all patients.

**Interventions:** Early diagnosis and treatment with combination of third-generation cephalosporins plus quinolones for a minimum of 3 weeks is necessary to avoid severe sequelae and death.

**Outcomes:** The first 3 patients had a good evolution, whereas the last patient had multiple brain abscesses and hydrocephalus requiring treatment with a ventriculoperitoneal shunt.

Lessons: The highlights of our study are that all infants were exclusively breastfed, no diarrhea observed and the negative coproculture for all the 4 patients, which is relatively rare for *Salmonella* infection.

**Abbreviations:** 3GC = third-generation cephalosporin, CSF = cerebrospinal fluid, DNA = deoxyribonucleic acid, HIV = human immunodeficiency virus, PCR = polymerase chain reaction.

Keywords: case reports, exclusive breastfeeding, infant, meningitis, Salmonella panama

# 1. Introduction

Nontyphoid *Salmonella* meningitis remains a threat for infants below 2 years of age in both developing and developed countries. However, the pathway of such infections, especially in exclusive breastfeeding infants, has not been well characterized. *Salmonella enterica* subsp. *enterica* serovar Panama was isolated for the first time as part of a food-borne outbreak among soldiers stationed in Panama in 1934.<sup>[1]</sup> Since then, *Salmonella panama* was isolated from food, animals, and water. It belongs to serogroup D1 and causes gastroenteritis in humans. This serotype especially has

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been associated with invasive diseases such as bacteremia and meningitis in children.<sup>[2]</sup> Infections usually occur after eating contaminated food or consumption of contaminated breast milk. In French Guiana, nearly 50% of *Salmonella* serotypes isolated from human infections belong to serotypes rarely encountered in metropolitan France. Moreover, nearly 2/3 of them have also been isolated from patients.<sup>[3]</sup>

Here, we analyzed data related to nontyphoid *Salmonella* meningitis in infants in our center in order to clarify the comprehensive features of nontyphoid *Salmonella* meningitis, including clinical characteristics, acute complications, and long-term outcome.

# 2. Patients and methods

Cayenne Hospital is as a referral center for primary care facility situated in Cayenne the main city of in French Guiana. From 2011 to 2016, we identified 4 cases of *Salmonella* meningitis referred to the Paediatrics and Surgery Unit. Medical records of the 4 pediatric cases admitted with spontaneous *Salmonella* meningitis were reviewed. The entry criteria for diagnosis were the isolation of *Salmonella* species in cerebrospinal fluid (CSF) culture, which further supported infection based on pleocytosis (>30/ $\mu$ L) with predominant neutrophilia and hypoglycorrhachia. Other following informations were retrieved: clinical presentations, demographic features, laboratory data, acute complications at hospitalization, antibiotic therapy, and longterm outcomes.

Moreover, for each case, family *Salmonella* contact exposure was investigated through bacteriological analysis of water, breast milk, and feces.

Consent: For each case report, the parents have written a documented and informed consent. They gave their written consent for the case report to be published.

Conflict of interest statment: The authors have no funding and conflicts of interest to disclose.

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#### 2.1. Biological methods

Hemoculture and coproculture were used as complementary examinations for the isolation of *Salmonella*. Identification of *Salmonella* spp. was based on conventional techniques as well as automated instruments including Vitek-2 (bioMérieux, Marcyl'Etoile, France), API 20 NE method (bioMerieux) or recently mass spectrometry (Microflex, Bruker Daltonics, Bremen, Germany).

The EvaGreen real-time polymerase chain reaction (PCR) assay has been used for identification of *S. enterica* subsp. *enterica* serovar Panama.<sup>[4]</sup> Total deoxyribonucleic acid (DNA) was extracted from the *Salmonella* spp. isolated strains with the Wizard Genomic DNA purification kit (Promega, Fitchburg, WI). The DNA was resuspended in a rehydration buffer provided with the Wizard kit. The Singleplex PCR was performed in a reaction volume of 50  $\mu$ L containing DNA (2  $\mu$ L for the InstaGene matrix or 1  $\mu$ L diluted 10-fold for Wizard). This molecular characterization of *S. enterica* serotype was performed at the Enteric Bacterial Pathogens Unit of the Institut Pasteur, Paris, France.<sup>[3]</sup>

#### 2.2. Ethical consideration and regulatory

Patients' medical records were retrospectively reviewed, and all data collected were anonymized in standardized forms according to procedures of the Commission Nationale de l'Informatique et Libertés (the French information protection commission). Moreover, all the participants have signed informed consent, before participating in the study.

#### 3. Results

We have reviewed 4 medical charts of 4 infants admitted for *Salmonella* meningitis in our center. They did not receive any treatment before admission to the hospital. All the 4 cases met the diagnosis criteria of *Salmonella* meningitis (isolation of *Salmonella* in the CSF, pleiocytisis, and hypoglycorachia). Data about the acute phase of *Salmonella* meningitis were summarized in

Table 1. Human immunodeficiency virus (HIV) infection and other risk factors for invasive disease were absent in our cases. Our 4 patients had an atypical clinical presentation: all had fever with vomiting, between 1 and 7 days before diagnosis. None of them had presented diarrhea. Two of them presented seizures before admission to hospital. All had signs of septic shock at admission. Neurological signs like lethargy, irritability, and bulging anterior fontanel were present in all patients. Biological signs were not different from other bacterial meningitis. No diarrhea was observed and the coproculture was negative for all patients. The laboratory findings were listed in Table 1. The clinical strains of *S. panama* were isolated from the CSF of all the infants. The investigation of the family *Salmonella* contact exposure was negative for all the patients.

During hospitalization, all the children had a brain magnetic resonance imaging and computerized tomography scan to detect acute intracranial complications and to diagnose ventriculitis. Table 1 summarizes the acute complications and outcomes in our patients with *Salmonella* meningitis. The 3 first patients had a less severity of the disease with a good evolution, whereas the last patient had multiple brain abscesses and hydrocephalus requiring treatment with a ventriculoperitoneal shunt. He also had deafness and lack of eye tracking. We have noted no deaths.

#### 4. Discussion

Lumbar puncture is easily performed in children, but sometimes the clinical presentation of meningitis may be atypical and delay its completion. The highlights of our study are that all infants were exclusively breastfed, no diarrhea observed and the negative coproculture for all the 4 patients, which is relatively rare for *Salmonella* infection.

Several studies<sup>[5,6]</sup> have reported cases with digestive infection in the previous days and a positive coproculture for salmonella. In all patients, we were able to make an etiological investigation of the source of salmonella (coproculture among parents and siblings, study of consumed water). This etiological research was negative. None of these families amounted turtles or snakes. We

Table 1

Summary table of clinical characteristics, laboratory, and long-term outcome.

Variables	Patient 1	Patient 2	Patient 3	Patient 4
Admission features				
Year of occurrence	2011	2012	2013	2016
Sex	F	F	F	М
Breastfeeding	Yes	Yes	Yes	Yes
Age at onset, mo	3	6	6	7
Medical background				
Immune deficiency	No	No <sup>*</sup>	No	No
Sickle cell disease	No	No	No	No
Born from a HIV-infected mother	No	No	No	Yes
Duration of fever before diagnosis, d	7	7	1	5
Temperature on admission, °C	39	39	39	38.5
Diarrhea	No	No	No	No
Vomiting	Yes	Yes	Yes	No
Seizures before admission	No	No	Yes	Yes
Seizures at hospital	No	No	Yes	Yes
Lethargy	Yes	Yes	Yes	Yes
Irritability	Yes	Yes	Yes	Yes
Poor feeding	Yes	Yes	Yes	Yes
Bulging anterior fontanel	Yes	Yes	No	No
Septisshoc	No	Yes	Yes	Yes

(continued)

Arthonic betwee heightsteam         No         No         No         Yes           Densing of Lancourd GG, mykryd         45:300         45:500         45:500         45:300           Densing of Lancourd GG, mykryd         45:300         45:500         45:300         45:300           Darniska of Lancourd I devirage         Yes         Yes         Yes         Yes           Dability         No         No         No         Yes         Yes           Dability         No         No         No         No         Yes           Decision for considered         No         No         No         No         No           Actin considerations         No         No         No         No         No         No           Subdatiz collection         No         No         No         No         No         Yes           Intracrianic forgenity accurate         Terregrafic forgenity         Terregrafic forgenity         Yes         Yes           Corra in hospital         No         No         No         No         No         Yes           Finder accurate         Terregrafic forgenity         No         No         No         Yes           Corcarin intraction         No         N	Variables	Patient 1	Patient 2	Patient 3	Patient 4
Duration in hospitalization, days, da	Antibiotic before hospitalization	No	No	No	Yes
Design of Quanchener3GC, myshipki45/30045/30045/300Duration of twinnerwer1.019212145Cordion at tachangeYesYesYesDisbuiltyNoNoNoYesDisbuiltyNoNoNoYesDisbuiltyNoNoNoYesPolar nortw wakenessNoNoNoNoPolar nortw wakenessNoNoNoNoIndian of the state of the st	Duration of hospitalization, days	19	21	22	47
Duration of restruct1921212145SurvialYesYesYesYesYesSurvialNoNoNoYesYesDispulityNoNoNoYesYesOracing satureNoNoNoNoYesAuroscensesNoNoNoNoNoAuroscensesNoNoNoNoNoCorra in fragenial complicationsNoNoNoNoYesSubdural CorsonoursesNoNoNoNoNoNoCarra in fragenial complicationsNoNoNoNoNoNoBrain abacessNoNoNoNoYesYesCarra in fragenial infractionNoNoNoNoYesHydrocophalusNoNoNoNoYesCarra in frageniaNoNoNoYesCarra in frageniaNoNoNoYesUnderstand developmentUnderstandNoNoNoDebyedNoNoNoNoNoNotaria developmentUnderstandNoNoNoDebyedNoNoNoNoNoNotaria developmentUnderstandNoNoNoDebyedNoNoNoNoNoNotaria developmentUnderstandNoNoNoDebyedNoNoNoNo <td< td=""><td>Dosing of Quinolone/3GC. ma/ka/d</td><td>45/300</td><td>45/300</td><td>45/300</td><td>45/300</td></td<>	Dosing of Quinolone/3GC. ma/ka/d	45/300	45/300	45/300	45/300
Condition at disknaps         Yes         Yes <thyes< th=""> <thyes< th=""> <thyes< th=""></thyes<></thyes<></thyes<>	Duration of treatment. d	19	21	21	45
Survival         Yes         Yes         Yes         Yes           Disability         No         No         No         Yes           Organ posturin         No         No         No         Yes           Department         No         No         No         No         No           Andre complications and nationnes         No         No         No         No         No           Andre complications and nationnes         No         No         No         No         No           Subdivid Collision         No         No         No         No         No         Yes           Intracruital focal infection         No         No         No         No         Yes           Engretin         No         No         No         No         Yes           Carcing infection         No         No         No         No         No           Togeterm culture development         No         No         No         No         No           Togeterm culture development         No         No         No         No         No           Togeterm culture development         No         No         No         No         No           Togeterm c	Condition at discharge				
DisabilityNoNoNoYesYesFord notar weaknessNoNoNoYesYesEnlagseNoNoNoNoYesLevel of conscionancesYesYesLevel of conscionancesNoNoYesYesLevel of conscionancesNoNoNoYesYesInteractial conflictionNoNoNoNoNoNoSubdurat colstonNoNoNoNoNoNoEmperinaNoNoNoNoYesYesCardena infractionNoNoNoNoYesHydrocephalusNoNoNoNoYesUnagreem cultorin developmentNoNoNoNoNoDelayddNoNoNoNoNoNoMindNoNoNoNoNoNoMindNoNoNoNoNoNoMindNoNoNoNoNoNoMindNoNoNoNoNoNoMindNoNoNoNoNoNoMindNoNoNoNoNoNoMindNoNoNoNoNoNoMindNoNoNoNoNoNoMindNoNoNoNoNoNoMindNo <t< td=""><td>Survival</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></t<>	Survival	Yes	Yes	Yes	Yes
Opgoing searmNoNoNoNoNoNoNoNoDelayonNoNoNoNoNoNoNoAcute complications and nationersNoNoNoNoNoLevel of conscionaresNoNoNoNoNoNoCons in hresplatNoNoNoNoNoNoNoNophilosoficationsNo	Disability	No	No	No	Yes
Field interar visalmessNoNoNoNoNoDelapseNoNoNoNoAcite complications and outcomesNoNoLevel of consolisamesticNoNoNoIntracranial complicationsNoNoNoNoSubdural collectionNoNoNoNoIntracranial complicationsNoNoNoNoEmperinaNoNoNoNoNoBran rateoussNoNoNoNoYesCarrobal infractionNoNoNoNoNoBran rateoussNoNoNoNoNoHydrocephalesNoNoNoNoNoCarrobal infractionNoNoNoNoNoHydrocephalesNoNoNoNoNoCong-term outcome developmentNoNoNoNoNoDelayedNoNoNoNoNoNoMildNoNoNoNoNoNoNormalYesYesYesYesNoHydrocephalyNoNoNoNoYesPelapsetNoNoNoNoYesMildNoNoNoNoYesMildNoNoNoNoYesMildNoNoNoNoYesHydrocephalyNoNoNoNo </td <td>Ongoing seizure</td> <td>No</td> <td>No</td> <td>Yes</td> <td>Yes</td>	Ongoing seizure	No	No	Yes	Yes
RelignationNoNoNoNoNoAction complications and nucromsComa in hexpitalNoNoNoNoIntracarrial complicationsIntracarrial complicationsIntracarrial complicationsBallotari collectionNoNoNoIntracarrial complicationsErangeriaNoNoNoNoBran abscossNoNoNoNoCartical infractionNoNoNoNoYesCartical infractionNoNoNoNoYesCartical infractionNoNoNoNoYesCartical infractionNoNoNoNoYesCartical infractionNoNoNoNoYesCartical infractionNoNoNoNoYesCartical infractionNoNoNoNoYesCartical infractionNoNoNoNoYesCartical infractionNoNoNoNoYesCartical infractionNoNoNoNoNoModerationNoNoNoNoNoModerationNoNoNoNoNoModerationNoNoNoNoNoModerationNoNoNoNoNoModerationNoNoNoNoNoMore analyNoNoNoNoNo <td>Focal motor weakness</td> <td>No</td> <td>No</td> <td>No</td> <td>Yes</td>	Focal motor weakness	No	No	No	Yes
Acing complications and outcomes         No         No         No         Yes           Level of consciousness         No         No         No         No         No           Subcural collection         No         No         No         No         No           Subcural collection         No         No         No         No         No           Grants in heapital         No         No         No         No         No         No           Caretizal infraction         No         No         No         No         No         No           Horizonalis tassess         No         No         No         No         No         No           Caretizal infraction         No         No         No         No         No         No           Delayod         No         No         No         No         No         No         No           Moder disaulity         -         -         -         -         -         -           Severe         No         No         No         No         No         No         No           Moder disaulity         -         -         -         -         -         - <t< td=""><td>Relapse</td><td>No</td><td>No</td><td>No</td><td>No</td></t<>	Relapse	No	No	No	No
Level of onsciousness         Name         No         Yes         Yes           Intracransial complications         No         No         No         No         No           Subdural collection         No         No         No         No         No         No           Emin attacate docal infection         No         No         No         No         No         No           Garbaper and trackers         No         No         No         No         No         No           Carabra infactores         No         No         No         No         No         No           Moradra infactores         No         No         No         No         No	Acute complications and outcomes				
Dors in hospital         No         No         Yes         Yes           Intracranial complications         No         No         No         No           Subdural collection         No         No         No         No         No           Empyema         No         No         No         No         No         No           Carebral infaction         No         No         No         No         No         No           Ventricutilis         No         No         No         No         No         No           Cong-term outcome divelopment         Delayed         No         No         No         No         No           Delayed         No         No         No         No         No         No         No           Midro ristality         No         No         No         No         No         No         No           More ristality         No         No         No         No         No         No         No           More ristality         No         No         No         No         No         No         No           More ristality         No         No         No         No         No <td< td=""><td>Level of consciousness</td><td></td><td></td><td></td><td></td></td<>	Level of consciousness				
Intracenal complications         Interaction         No         No         No         No           Subdural collection         No         No         No         No         No           Engranzational conditional interction         No         No         No         No         No           Brain atseess         No         No         No         No         No         Yes           Carebrai infarction         No         No         No         No         No         Yes           Unordermational constraints         No         No         No         No         No         Yes           Long-term outcome divelopment	Coma in hospital	No	No	Yes	Yes
Bit of the second sec	Intracranial complications			100	100
Intracential focal infection         No	Subdural collection	No	No	No	No
Instrument         NO         NO         NO         NO         NO         NO         NO           Brayma         NO         NO         NO         NO         NO         Yes           Caretbal infraction         NO         NO         NO         NO         Yes           Ventribuits         NO         NO         NO         NO         Yes           Long-term outcome development           NO         NO         NO         Yes           Delayed         NO         NO         NO         NO         NO         NO         NO           Moderatio         NO         NO         NO         NO         NO         NO         NO           Moderatio         NO         NO         NO         NO         NO         NO         NO           Marcoaphaly         NO         NO         NO         NO         NO         NO         Yes         Yes           Speech language         NO         NO         NO         NO         Yes         NO         Yes           Visual deficit         NO         NO         NO         NO         Yes         NO         Yes         NO         Yes         NO	Intracranial focal infection	No	No	No	Yes
Dright access         NO	Empyema	No	No	No	No
Data Bacters         ND	Brain abscess	No	No	No	Ves
No         No         No         No         No         No         No           Hentricultis         No         No         No         No         No         No           Delayed         No         No         No         No         Yes           Delayed         No         No         No         No         Yes           Moderate         No         No         No         No         No           Midd         No         No         No         No         No           Hearing problems         No         No         No         No         No           Hearing problems         No         No         No         No         No         No           Speech language         No         No         No         No	Cerebral infarction	No	No	No	Ves
Indit Additional High Conceptibilities         NO         NO         NO         NO         Yes           Long-term outcome development   No         No<	Ventriculitie	No	No	No	No
no	Hudrocophalus	No	No	No	Voc
Data year         No         No         No         No         Year           Delayed         No         No         No         No         Year           Motor disability         No         No         No         No         No           Motor disability         No         No         No         No         No           Motor disability         No         No         No         No         No           Marrat         Yes         Yes         Yes         Yes         Yes           Eplilensy         No         No         No         Yes         Yes           Visual deficit         No         No         No         Yes         Yes           Visual deficit         No         No         No         Yes         Yes           Normal         Yes         Yes         Yes         Yes         No           Normal         No         No         No         No         Yes           Normal         Yes         Yes         Yes         No         Yes           Normal         Yes         Yes         Yes         No         No         No           Total WBC, GL         6.31         5.94	Long term outcome development	110	NO	NO	165
Delayd         NO         NO         NO         NO         Pers           Severe1         No         No         No         No         No         No           Moderate         No         No         No         No         No         No         No           Mild         No         No         No         No         No         No         No           Hearing problems         No         No         No         No         Yes         Yes         No           Hearing problems         No         No         No         No         Yes         No         Yes         No         Yes         No         Yes         No         Yes         No         Yes         No         Yes         Yes         No         Yes         Yes         No         Yes		No	No	No	Vee
Walds Baselinity         No         Yes         Yes         Yes         No         No         No         No         Yes         No         No <td>Delayeu Motor dissbility</td> <td>INU</td> <td>INU</td> <td>INU</td> <td>res</td>	Delayeu Motor dissbility	INU	INU	INU	res
Selevite         NO         NO         NO         NO         NO           Moderate         No         No         No         No         No           Mild         No         No         No         No         No           Normal         Yes         Yes         Yes         No           Epileps/         No         No         No         Yes           Epileps/         No         No         No         No           Microcephaly         No         No         No         No           Hydrocephaly         No         No         No         No           Speech language         No         No         No         Yes           Abnormal         Yes         Yes         Yes         No           Normal         Yes         Yes         Yes         No           Speech language         No         No         No         Yes           Normal         Yes         Yes         Yes         No           Biological data         Test         Yes         Yes         No           Fortilin, µg/L         6.1         Test         Test         Test           Fortilin, µg/L         6.1 </td <td>Motor disability</td> <td>Na</td> <td>Ne</td> <td>Na</td> <td>Vee</td>	Motor disability	Na	Ne	Na	Vee
moderate         NO         NO         NO         NO         NO           Mild         No         No         No         No         No           Normal         Yes         Yes         Yes         No         No           Hearing problems         No         No         No         No         Yes           Epliepsy         No         No         No         No         Yes           Microcoephaly         No         No         No         No         No           Visual deficit         No         No         No         No         Yes           Speech language         No         No         No         No         Yes           Abnormal         Yes         Yes         Yes         No         No           Biological data         -         -         -         -         -           Peripheral blood data         -         -         -         -         -         -           Itymplicits, G/L         0.6         9.3         7.3         10.4           Lymphocytes, G/L         0.66         9.3         7.3         10.4           Hemoglobin level, G/L         0.6         0.9         0.8	Severe	NO	NO	NO	Yes
Mind         No         Yes         Yes         No         No         No         Yes         No         No         No         No         No         No         No         No	Moderate	NO	NO	NO	NO
Normal         Yes         Yes         Yes         No           Hearing problems         No         No         No         No         Yes           Epliepsy         No         No         No         No         No           Hdroccephalus         No         No         No         No         No           Visual deficit         No         No         No         No         Yes           Speech language         No         No         No         No         Yes           Abnormal         Yes         Yes         Yes         Yes         No           Biological data         -         -         -         -         -           Peripheral blood data         -         7.7         9.0         3.3         3.6           Nutrophils, G/L         6.31         5.94         0.36         1.34           Lymphocytes, G/L         0.89         2.70         2.44         2.05           Platelet, G/L         10.6         9.3         7.3         10.4           Ferritin, µg/L         6.1         -         -         -           GRP, mg/L         140         212         191         270           Hemoglobi	Mild	No	No	No	NO
Heaming problems         No         No         No         No         No         No         No         Yes           Epliepsy         No         No         No         No         No         No           Hydrocephaly         No         No         No         No         No         No           Visual deficit         No         No         No         No         Yes           Speech language         No         No         No         No         Yes           Mormal         No         No         No         No         Yes           Normal         Yes         Yes         Yes         No         No           Biological data         -         -         -         -         -           Total WBC, GL         6.31         5.94         0.36         1.34           Lymphocytes, GL         0.89         2.70         2.44         2.05           Platelet, GL         10.6         9.3         7.3         10.4           Hemoglobin levet, G/dL         10.6         9.3         7.3         10.4           GRP, mg/L         410         2.12         191         270           Hemoglobin levet, G/dL         6.1	Normal	Yes	Yes	Yes	No
Epilepsy         No         No         No         No         No         No         No           Microcephaly         No         No         No         No         No         No         No           Visual deficit         No         No         No         No         No         Yes           Speech language         No         No         No         No         Yes           Anormal         Yes         Yes         Yes         Yes         No           Normal         Yes         Yes         Yes         No         No           Biological data         Yes         Yes         Yes         No         No           Peripheral blood data         7.7         9.0         3.3         3.6           Neutrophis, G/L         6.31         5.94         0.36         1.34           Lymphocytes, G/L         0.69         2.70         2.44         2.05           Platelet, G/L         10.6         9.3         7.3         10.4           Ferritin, μg/L         6.1         -         -         -           CRP, mg/L         6.4         7         -         -         -           Hemoglobin level, G/L         6 <td>Hearing problems</td> <td>No</td> <td>No</td> <td>No</td> <td>Yes</td>	Hearing problems	No	No	No	Yes
Microcephaly         No         No         No         No         No         No         No         No           Hydrocephalus         No         No         No         No         No         Yes           Speech language         No         No         No         No         No         No         Yes           Abnormal         Yes         Yes         Yes         Yes         No         No           Normal         Yes         Yes         Yes         Yes         No         No           Biological data         Total WBC, G/L         7.7         9.0         3.3         3.6           Neutrophils, G/L         6.31         5.944         0.36         1.34           Lymptocytes, G/L         0.89         2.70         2.44         2.05           Platelet, G/L         3.06         182         239         101           Hemoglobin level, G/dL         10.6         9.3         7.3         10.4           Ferritin, μg/L         6.1         -         -         -           GR/ mg/L         140         212         191         270           Hemoglobin electrophoresis         AA         AA         AA         AA	Epilepsy	No	No	Yes	Yes
Hydrocephalus         No	Microcephaly	No	No	No	No
Visual deficit         No         No         No         No         No         Yes           Speech language         No         No         No         No         Yes           Abnormal         Yes         Yes         Yes         Yes         No           Normal         Yes         Yes         Yes         No         No           Biological data         ************************************	Hydrocephalus	No	No	No	Yes
Speech language         No         No         No         No         No         Yes           Abnormal         Yes         Yes         Yes         Yes         No           Biological data         ************************************	Visual deficit	No	No	No	Yes
AbnormalNoNoNoYesNoNormalYesYesYesYesNoBiological dataPeripheral blood dataTotal WBC, G/L7.79.03.33.6Neutrophils, G/L6.315.940.361.34Lymphocytes, G/L0.892.702.442.05Platelet, G/L306182239101Hemoglobin level, G/dL10.69.37.310.4Ferritin, $\mu g/L$ 6.1CRP, mg/L140212191270Hemoglobin level, G/L0.60.90.80.7IgG level, G/L6567IgA level, G/L0.60.90.80.7H/VNegativeNegativeNegativeNegativeCSF data1.261.932.92CoprocultureNegativeNegativeNegativeProtein, G/L1.531.261.932.92CoprocultureNegativeNegativeNegativeHemoculturePositivePositivePositiveHemoculturePositiveNegativeNegativeNoGNGNGNGNGram-negative bacterium identifiedS. panamaS. panamaS. panamaS. panamaS. panamaS. panama	Speech language	No	No	No	Yes
Normal         Yes         Yes         Yes         Yes         No           Biological data         Peripheral blood data	Abnormal	No	No	No	Yes
Biological data         Peripheral blood data           Total WBC, G/L         7.7         9.0         3.3         3.6           Neutrophils, G/L         6.31         5.94         0.36         1.34           Lymphocytes, G/L         0.89         2.70         2.44         2.05           Platelet, G/L         306         182         239         101           Hemoglobin level, G/dL         10.6         9.3         7.3         10.4           Ferritin, μg/L         6.1          7.3         10.4           CRP, mg/L         140         212         191         270           Hemoglobin electrophoresis         AA         AA         AA         AA           IgG level, G/L         6         5         6         7           IgA level, G/L         0.6         0.9         0.8         0.7           HW         Negative         Negative         Negative         Negative           CSF data         70         450         498         70         840           PMN, μL         252         149         25         647           Glucose, mmol/L         0.4         0.2         1.9         <0.1	Normal	Yes	Yes	Yes	No
Peripheral blood data           Total WBC, G/L         7.7         9.0         3.3         3.6           Neutrophils, G/L         6.31         5.94         0.36         1.34           Lymphocytes, G/L         0.89         2.70         2.44         2.05           Platelet, G/L         306         182         239         101           Hemoglobin level, G/L         10.6         9.3         7.3         10.4           Ferritin, $\mu g/L$ 6.1	Biological data				
Total WBC, G/L7.79.03.33.6Neutrophils, G/L6.315.940.361.34Lymphocytes, G/L0.892.702.442.05Platelet, G/L306182239101Hemoglobin level, G/dL10.69.37.310.4Ferritin, $\mu g/L$ 6.177.79.0101CRP, mg/L140212191270Hemoglobin electrophoresisAAAAAAAAIgG level, G/L6567IgA level, G/L0.60.90.80.7HIVNegativeNegativeNegativeNegativeCSF dataTotal WBC, $\mu L$ 45049870840PMN, $\mu L$ 25214925647Glucose, mmol/L0.40.21.932.92CoprocultureNegativeNegativeNegativeNegativeHemoculturePositivePositivePositivePositiveGram colorationGNGNGNGNGN	Peripheral blood data				
Neutrophils, $G/L$ 6.315.940.361.34Lymphocytes, $G/L$ 0.892.702.442.05Platelet, $G/L$ 306182239101Hemoglobin level, $G/dL$ 10.69.37.310.4Ferritin, $\mu g/L$ 6.177.1270CRP, $ng/L$ 140212191270Hemoglobin electrophoresisAAAAAAAAIgG level, $G/L$ 6567IgA level, $G/L$ 0.60.90.80.7HVNegativeNegativeNegativeNegativeCSF dataTotal WBC, $\mu L$ 45049870840PMN, $\mu L$ 25214925647Glucose, mmol/L0.40.21.932.92CoprocultureNegativeNegativeNegativeNegativeHemoculturePositivePositivePositivePositiveGram colorationGNGNGNGNGN	Total WBC, G/L	7.7	9.0	3.3	3.6
Lymphocytes, G/L         0.89         2.70         2.44         2.05           Platelet, G/L         306         182         239         101           Hemoglobin level, G/dL         10.6         9.3         7.3         10.4           Ferritin, μg/L         6.1         -         -         -         -           CRP, mg/L         140         212         191         270         -         -           Hemoglobin electrophoresis         AA         AA         AA         AA         AA         AA         AA         -	Neutrophils, G/L	6.31	5.94	0.36	1.34
Platelet, G/L         306         182         239         101           Hemoglobin level, G/dL         10.6         9.3         7.3         10.4           Ferritin, μg/L         6.1         -         -         -           CRP, mg/L         140         212         191         270           Hemoglobin electrophoresis         AA         AA         AA         AA           IgG level, G/L         6         5         6         7           IgA level, G/L         0.6         0.9         0.8         0.7           HV         Negative         Negative         Negative         Negative           CSF data         -         -         149         25         647           Glucose, mmol/L         0.4         0.2         1.9         <0.1	Lymphocytes, G/L	0.89	2.70	2.44	2.05
Hemoglobin level, G/dL         10.6         9.3         7.3         10.4           Ferritin, μg/L         6.1         -	Platelet, G/L	306	182	239	101
Ferritin, $\mu g/L$ 6.1CRP, mg/L140212191270Hemoglobin electrophoresisAAAAAAAAIgG level, G/L6567IgA level, G/L0.60.90.80.7HIVNegativeNegativeNegativeNegativeCSF data725214925Total WBC, $\mu L$ 25214925647Glucose, mmo/L0.40.21.9<0.1	Hemoglobin level, G/dL	10.6	9.3	7.3	10.4
CRP, mg/L140212191270Hemoglobin electrophoresisAAAAAAAAIgG level, G/L6567IgA level, G/L0.60.90.80.7HIVNegativeNegativeNegativeNegativeCSF data70840PMN, $\mu$ L25214925647Glucose, mmol/L0.40.21.9<0.1	Ferritin, µg/L	6.1			
Hemoglobin electrophoresisAAAAAAAAlgG level, G/L6567lgA level, G/L0.60.90.80.7HIVNegativeNegativeNegativeNegativeCSF data70840PMN, $\mu$ L25214925647Glucose, mmol/L0.40.21.9<0.1	CRP, mg/L	140	212	191	270
IgG level, G/L6567IgA level, G/L0.60.90.80.7HIVNegativeNegativeNegativeNegativeCSF dataTotal WBC, $\mu$ L45049870840PMN, $\mu$ L25214925647Glucose, mmol/L0.40.21.9<0.1	Hemoglobin electrophoresis	AA	AA	AA	AA
IgA level, G/L0.60.90.80.7HIVNegativeNegativeNegativeNegativeCSF dataTotal WBC, μL45049870840PMN, μL25214925647Glucose, mmol/L0.40.21.9<0.1	IgG level, G/L	6	5	6	7
HIVNegativeNegativeNegativeNegativeCSF dataTotal WBC, μL45049870840PMN, μL25214925647Glucose, mmol/L0.40.21.9<0.1	IgA level, G/L	0.6	0.9	0.8	0.7
CSF dataTotal WBC, $\mu$ L45049870840PMN, $\mu$ L25214925647Glucose, mmol/L0.40.21.9<0.1	HIV	Negative	Negative	Negative	Negative
Total WBC, μL45049870840PMN, μL25214925647Glucose, mmol/L0.40.21.9<0.1	CSF data	-	-	-	-
PMN, μL25214925647Glucose, mmol/L0.40.21.9<0.1	Total WBC, μL	450	498	70	840
Glucose, mmol/L0.40.21.9<0.1Protein, G/L1.531.261.932.92CoprocultureNegativeNegativeNegativeNegativeHemoculturePositivePositivePositivePositiveGram colorationGNGNGNGNGram-negative bacterium identifiedS. panamaS. panamaS. panama	PMN, μL	252	149	25	647
Protein, G/L1.531.261.932.92CoprocultureNegativeNegativeNegativeNegativeHemoculturePositivePositivePositivePositiveGram colorationGNGNGNGNGram-negative bacterium identifiedS. panamaS. panamaS. panama	Glucose, mmol/L	0.4	0.2	1.9	<0.1
Coproculture         Negative         Negative         Negative         Negative           Hemoculture         Positive         Positive         Positive         Positive         Positive           Gram coloration         GN         GN         GN         GN         GN           Gram-negative bacterium identified         S. panama         S. panama         S. panama         S. panama	Protein, G/L	1.53	1.26	1.93	2.92
HemoculturePositivePositivePositivePositiveGram colorationGNGNGNGNGram-negative bacterium identifiedS. panamaS. panamaS. panamaS. panama	Coproculture	Negative	Negative	Negative	Negative
Gram colorationGNGNGNGram-negative bacterium identifiedS. panamaS. panamaS. panama	Hemoculture	Positive	Positive	Positive	Positive
Gram-negative bacterium identified S. panama S. panama S. panama S. panama	Gram coloration	GN	GN	GN	GN
	Gram-negative bacterium identified	S. panama	S. panama	S. panama	S. panama

3GC = third-generation cephalosporins, CSF = cerebrospinal fluid, GN = gram-negative, PMN = polymorphonuclea, WBC = white blood cells. \* Full immunological investigation including congenital or acquired immunodeficiency.

could not find *Salmonella* in pet-reptiles. In French Guiana, domestic reptiles (snakes, turtles, etc.) are common in houses and their presence near habitations is a usual situation.<sup>[3]</sup> Exposure to domestic reptiles was involved in the contamination of infants by *Salmonella*.<sup>[3,7]</sup> Our investigations have not allowed us to find source of salmonella in these infants who were exclusively breastfed. However, a reptilian source of contamination has previously been investigated in French Guiana, and the overall frequency of carriage was 23.2%.<sup>[3]</sup>

Furthermore, some questions remain unanswered and in particular, scarcity of such infections in infants could be related to a low inoculum? None of the patients had an immune deficiency. The diagnosis of meningitis is easy with lumbar puncture performed in infants with septic shock. The serotype identification of *Salmonella* was made in the National Reference Center for *Salmonella* in France. *S. enterica* subsp. *enterica* serovar Panama was isolated for all of the patients. This serotype is known to cause invasive diseases such as meningitis in children.<sup>[1,2]</sup>

The currently recommended first-line treatment of Salmonella meningitis is a combination of third-generation cephalosporins (3GC) with quinolones for a minimum of 3 weeks.<sup>[8]</sup> This protocol was conducted for the 4 patients. The evolution was favorable in 3 of them. The fourth patient had a dramatic neurological outcome, though the delay between the onset of fever and diagnosis of meningitis was similar in all patients. No patient was immunosuppressed. But the patient who has had a dramatic outcome was born from HIV-infected mother. It is well described now that children born from HIV-infected mothers are at a high risk of developing bacterial infections.<sup>[9]</sup> Although Salmonella meningitis is rare in children, it remains a serious infection. Our study confirms the literature findings.<sup>[10]</sup> Early diagnosis and antibiotic treatment are necessary for a better therapeutic response and to prevent progression toward sequelae or death. A long-term effects monitoring for early developmental assessment for survivors is vital.

For all the 4 patients, a follow-up on psychomotor development with research of sensory disturbances was set up. We have noted no death among the 4 children and 1 patient had a severe neurologic outcome according to our monitoring.

#### 5. Conclusion

*Salmonella* meningitis is rare in infant but is severe with a high risk of sequelae in survivors. Early diagnosis and treatment with combination of 3GC plus quinolones for a minimum of 3 weeks is necessary to avoid severe sequelae and death. The long-term monitoring for survivors is useful to improve the functional prognosis.

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