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REVIEW ARTICLE
Chorioamnionitis and neonatal outcomes

Viral G. Jain [1]✉, Kent A. Willis [1], Alan Jobe [2] and Namasivayam Ambalavanan [1]

Chorioamnionitis or intrauterine inflammation is a frequent cause of preterm birth. Chorioamnionitis can affect almost every organ of the developing fetus. Multiple microbes have been implicated to cause chorioamnionitis, but "sterile" inflammation appears to be more common. Eradication of microorganisms has not been shown to prevent the morbidity and mortality associated with chorioamnionitis as inflammatory mediators account for continued fetal and maternal injury. Mounting evidence now supports the concept that the ensuing neonatal immune dysfunction reflects the effects of inflammation on immune programming during critical developmental windows, leading to chronic inflammatory disorders as well as vulnerability to infection after birth. A better understanding of microbiome alterations and inflammatory dysregulation may help develop better treatment strategies for infants born to mothers with chorioamnionitis.

INTRODUCTION
In 2015, 9.7% of all births in the US were preterm births,[1] which contributed to 75% of perinatal mortality and 50% of the long-term morbidity.[2] Chorioamnionitis triggers 40–70% of prematurity, with the incidence higher for lower gestational ages.[2–5] Acute chorioamnionitis or intrauterine inflammation (IUI) implies that a pregnant woman has an inflammatory or an infectious disorder of the chorion, amnion, or both, which, in turn, suggests that the mother and her fetus may be at an increased risk for developing serious complications.[6] Robust maternofetal proinflammatory immune responses triggered in chorioamnionitis result in early pregnancy termination by spontaneous preterm birth to preserve the life of the mother, though at the expense of the vulnerable fetus.[7]

While microorganisms are frequently associated with chorioamnionitis, it can occur as "sterile" intra-amniotic inflammation in the absence of demonstrable microorganisms and is induced by danger signals released under conditions of cellular stress, injury, or death.[8] Thus, acute chorioamnionitis is evidence of intra-amniotic inflammation and not necessarily intra-amniotic infection. Intra-amniotic infection and chorioamnionitis are commonly used interchangeably; however, these two conditions are not the same. Sterile inflammation (e.g., mediated via damage-associated molecular patterns),[9] environmental pollutants,[9–11] cigarette smoke,[12] and other toxicants have also been implicated in chorioamnionitis. Sterile inflammation is more frequent than intra-amniotic infection (i.e., microbe-associated intra-amniotic inflammation) in patients with preterm labor with intact membranes, preterm premature rupture of membranes, and an asymptomatic short cervix.[8,13–15] This inflammatory infiltrate is induced by the maternal inflammatory response from the intervillous space and decidua, as well as the fetal inflammatory response from the vessels of the umbilical cord and chorionic plate.

The inflammatory complications associated with chorioamnionitis have been well described, and these effects may last into adulthood.[16] Increasing evidence supports the concept that the ensuing neonatal immune dysfunction reflects the effects of inflammation on immune programming during critical developmental windows, leading to chronic inflammatory disorders as well as vulnerability to infection after birth.[17]

In this review, we discuss the microbiology and inflammatory pathways involved in chorioamnionitis followed by a brief discussion of the neonatal complications and management of chorioamnionitis.

DEFINITIONS AND STAGING OF CHORIOAMNIONITIS
Clinical chorioamnionitis has been defined as a broad clinical syndrome with any combination of fever, maternal or fetal tachycardia, uterine tenderness, foul-smelling amniotic fluid, or elevated white blood cell (WBC) count. However, the presence of one (or even more than one) of these signs and symptoms does not necessarily indicate intrauterine/intra-amniotic inflammation —or that histopathologic chorioamnionitis is present. In a study of patients with preterm clinical chorioamnionitis, 24% had no evidence of either intra-amniotic infection or intra-amniotic inflammation, and 66% had negative amniotic fluid cultures. Interestingly, only 12% of patients with acute histological chorioamnionitis at term had detectable microorganisms in the placenta.[18] Patients without microbial invasion of the amniotic cavity or intra-amniotic inflammation had lower rates of adverse outcomes than those with microbial invasion of the amniotic cavity and/or intra-amniotic inflammation.[19]

The term chorioamnionitis has been loosely used to label a heterogeneous array of conditions characterized by infection and inflammation or both, with a consequent marked variation in clinical management for mothers with chorioamnionitis and their newborns. Due to the imprecise definition and to the variable clinical manifestations, the expert panel led by National Institute of

[1]Division of Neonatology, Department of Pediatrics, The University of Alabama at Birmingham, Birmingham, AL, USA. [2]Perinatal Institute, Department of Pediatrics, Cincinnati Children's Hospital, Cincinnati, OH, USA. ✉email: viral_jain@live.com

Child Health and Human Development (NICHD) proposed to replace the term chorioamnionitis with a more general, descriptive term, "IUI or infection or both," abbreviated as "Triple I." The panel proposed a classification for Triple I and recommended approaches to evaluation and management of pregnant women and their newborns with a diagnosis of Triple I.[6] In these guidelines, fever alone during labor is classified separately, because excluding fever as a prerequisite for the criteria of clinical chorioamnionitis increases sensitivity for the identification of neonatal sepsis.[20] Suspected Triple I is defined as fever with one or more of the following symptoms: leukocytosis, fetal tachycardia, or purulent cervical discharge. To be confirmed, "suspected Triple I" should be accompanied by evidence of amniotic fluid infection (e.g., positive Gram stain for bacteria, low amniotic fluid glucose, high WBC count in the absence of a bloody tap, and/or positive amniotic fluid culture results) or histopathological infection/inflammation in the placenta, fetal membranes, or the umbilical cord vessels.[6]

Histopathological chorioamnionitis is defined as diffuse infiltration of neutrophils into the chorioamniotic membranes.[21] If it affects the villous tree, this represents acute villitis. Inflammatory processes involving the umbilical cord (umbilical vein, umbilical artery, and the Wharton's jelly) are referred to as acute funisitis. These findings represent the histological evidence of the fetal inflammatory response syndrome (FIRS).[22] Neutrophils are not normally present in the chorioamniotic membranes and migrate from the decidua into the membranes in cases of acute chorioamnionitis. Thus, the neutrophils infiltrating the choriodecidua are maternal in origin, while neutrophils in the amniotic fluid are mixture of fetal and maternal origin, and those infiltrating the umbilical cord are of fetal origin.[23]

Although several grading systems have been used to define the severity of chorioamnionitis, the criteria developed by Redline et al.,[21] and recommended by the Amniotic Fluid Infection Nosology Committee of the Perinatal Section of the Society for Pediatric Pathology, are the most widely accepted. Herein acute inflammatory lesions of the placenta are classified into two categories: maternal inflammatory response and fetal inflammatory response. The term stage (Stages 1–3) refers to the progression of the process based on the anatomical regions infiltrated by neutrophils; the term grade refers to the intensity of the acute inflammatory process at a particular site (Grades 1–3).

MICROBIOLOGY OF CHORIOAMNIONITIS
Acute chorioamnionitis is often thought to be due to ascending infection—diffuse ascending colonization of the endometrial–chorionic potential space with extension into the fetal membranes, the amniotic fluid, and ultimately the fetus.[24] This hypothesis was proposed as a result of the association of bacteria of the urogenital tract, such as *Mycoplasma* spp, *Ureaplasma* spp, and Group B *Streptococcus* (GBS) with chorioamnionitis and with the colonization of placental/fetal membranes.[13,25–30] Other organisms such as *Gardenella vaginalis* and *Escherichia coli* and fungi such as *Candida* have been associated with chorioamnionitis.[3,31–33] Polymicrobial infection is seen in about 30% of the cases.[34]

However, the presence of bacteria is not necessarily indicative of infection. The vaginal microbiome changes during pregnancy.[35] While currently controversial due to long standing evidence supporting sterility of the womb, evidence is mounting that the fetus does not exist in a sterile environment and the placental microbiome is likely similar to the oral microbiome.[36] The presence of live microbes in fetal organs during pregnancy have broader implications toward the establishment of immune competency and priming before birth.[37] The microbiome of the chorion–amnion changes with chorioamnionitis to more urogenital and mouth-resembling commensal bacterial.[29] Decreased *Lactobacillus* spp. with increased *Ureaplasma* spp. in the vagina predicts preterm birth.[29,38] Animal studies support the correlation between *Ureaplasma*

presence and preterm birth.[39] The association between the placental and oral microbiomes provides a potential explanation for the presence of commensal oral bacteria (such as *Streptococcus* and *Fusobacterium* spp.) in chorioamnionitis via the hematogenous spread of bacteria during pregnancy into the amniotic cavity.[40] Although the placental membrane microbiota are altered in histologic chorioamnionitis, there are no observable impacts with either betamethasone or antibiotic therapy.[29] In addition, various TORCH pathogens, including *Toxoplasma gondii*, other viruses (*Listeria monocytogenes*, *Treponema pallidum*, parvovirus, HIV, varicella zoster virus, among others), *Rubella*, *Cytomegalovirus*, and Herpesviruses 1 and 2, and more recently, Zika virus, as well as *Plasmodium* spp., have been implicated in chorioamnionitis.[41–43] Intra-amniotic infection with fungi has also been found in women who become pregnant while using intrauterine contraceptive devices.[44] In contrast to the ascending infections causing inflammation primarily in the choriodecidua and amnion, organisms invading through the hematogenous route cause inflammation primarily in the placental villi and intervillous space.[45]

Experimental evidence exists that bacteria can cross intact membranes, and rupture of the membranes is therefore not necessary for bacteria to reach the amniotic cavity.[46] Thus, intra-amniotic infection has been documented in patients with preterm labor with intact membranes as well as in preterm premature rupture of the membranes and cervical insufficiency.[13,24,47]

IMMUNOLOGY/CYTOKINES ASSOCIATED WITH CHORIOAMNIONITIS
The inflammatory mediators during chorioamnionitis are implicated as causative agents of prematurity.[48] Bacterial colonization of the amniotic fluid without inflammation is relatively benign. Intra-amniotic inflammation is associated with adverse perinatal outcomes whether or not microbes are detected.[31] This implies that inflammation, regardless of etiology, is the primary driver of morbidity seen with chorioamnionitis.

Currently available therapies for chorioamnionitis and/or preterm labor rely on antibiotics, progesterone, and antenatal corticosteroids.[6,49] However, these treatments are not generally effective, and there are many adverse effects.[50,51] Antibiotics, often fail to prevent chorioamnionitis-associated morbidities[52,53] due to persistent inflammatory mediators that account for fetal and maternal injury.[54] Exposure to chorioamnionitis activates the neonatal immune system in utero with potentially long-term health consequences.[55]

The amniotic membrane safeguards the maturing fetus against exposure to pathogenic organisms, while also providing an immunologically privileged site designed to protect the allogeneic fetus from maternal rejection. Alteration in this safeguard mechanism leads to chorioamnionitis.[56] Microbial invasion or introduction of inflammatory stimuli into the amniotic cavity induces a robust local inflammatory response. In the early stages of chorioamnionitis, maternal immune responses dominate, infiltrating the fetal membranes.[16] The elevated gradient of chemokine concentrations that is established across the chorioamniotic membranes and the decidua favors the diffuse infiltration of maternal neutrophils into the chorioamniotic membranes.[57] In the absence of microorganisms, danger signals released by cells under stress conditions or cell death can induce intra-amniotic inflammation.[58,59] Conversely, infection without a fetal/maternal inflammatory response may not cause labor and preterm delivery.[19] If the infectious or inflammatory process progresses, fetal leukocytes then infiltrate leading to a dramatic increase in the concentrations of proinflammatory cytokines such as interleukin (IL)-1β, IL-4, IL-6, IL-8, and IL-18 and chemokines such as IL-8, C-X-C chemokine motif ligand 6 (CXCL6), and CXCL10.[24] This condition is known as the fetal inflammatory response syndrome (FIRS).[7]

FIRS has been classically defined by an elevated cord plasma IL-6 concentration, which is a marker of IUI and a predictor of preterm birth.[7,60] The prevalence of FIRS, defined by fetal plasma IL-6 level >11 pg/mL, is about 50%, and these infants are at a higher rate of severe neonatal morbidity.[7] Recently, IL-17A has also been shown to be a vital component in the initiation of FIRS and a potential contributor to the later development of chronic conditions caused by fetal exposure to in utero inflammatory and/or infectious processes.[61,62] IL-17A is an important component of host immune responses that target and eliminate extracellular pathogens, including Gram-positive, Gram-negative, and fungal microbes.[63,64] Compared to adults, newborns have lower baseline levels of IL-17A, which may diminish their ability to generate proinflammatory immune responses and increase susceptibility to infection. IL-17A production is not dependent upon immune maturation or advancing gestational age.[65] IL-17A is produced by T helper 17 (Th17) cells. Developmental deficiencies in Th17 arm are associated with an increased risk of systemic infection in premature neonates.[65] Induction of Th17 cells from naive helper T lymphocytes is triggered by IL-1β, IL-6, IL-21, and IL-23 in coordination with transforming growth factor (TGF)-β and RAR-related orphan receptor-γ. Low levels of TGF-β promote Th17 lymphocyte differentiation, whereas high levels stimulate the transcription factor forkhead box P3 to generate regulatory T cells (Tregs). Treg cells are important in suppressing immune activity and maintenance of maternal–fetal tolerance.[66] Because of their opposing immune responses, the Th17/Treg balance is vital for maintaining fetal immune homeostasis. Chorioamnionitis enhances Th17-like responses in preterm infants[67] and reduces the functionality of Tregs.[68] However, further studies are needed to elucidate the role of IL-17A and TH17/Treg balance in chorioamnionitis.

Lastly, IL-1β is another important cytokine implicated in the pathogenesis of chorioamnionitis-mediated preterm birth in mice,[69] rhesus monkeys,[70] and humans.[71] There have been several studies that have correlated the increase in IL-1β with preterm birth in humans as well as in several animal species[24] and also with spontaneous delivery at term in humans.[72] It is thought that IL-1β overproduction heralds labor, regardless of the presence of infection.[73] Moreover, elevated IL-1β blood concentration in human neonates has been associated with preterm birth.[74] IL-1β concentration and bioactivity increases in the amniotic fluid of women with preterm labor and infection, and elevated maternal plasma IL-1β are associated with preterm labor.[75] IL-1 signaling mediates the initiation, amplification of inflammation, and regulation of survival and activity of neutrophils at the maternal–fetal interface during chorioamnionitis via the IRAK1 pathway.[71] IRAK1, a downstream mediator in the Toll-like receptor (TLR) and IL-1R signaling pathways, has been recently identified as the critical mediator of inflammation-induced preterm birth.[76] As such, IL-1β or IRAK1 may be a potential therapeutic target for chorioamnionitis and its associated morbidities.[71,76]

Extensive studies have been conducted to determine whether any of these inflammatory markers have diagnostic and prognostic value in cases of suspected intra-amniotic inflammation/infection. Meta-analyses have shown that there is insufficient evidence to support the use of any inflammatory markers including IL-6 in maternal blood for diagnosis of chorioamnionitis in preterm premature rupture of membranes.[77]

ADVERSE OUTCOMES
Chorioamnionitis is associated with an approximately 2–3.5-fold increased odds of neonatal adverse outcomes.[78] These adverse outcomes include perinatal death, early-onset neonatal sepsis, septic shock, pneumonia, meningitis, intraventricular hemorrhage (IVH), cerebral white matter damage, and long-term disability including cerebral palsy, retinopathy of prematurity, necrotizing enterocolitis

(NEC) as well as morbidity related to preterm birth[79–84] (Fig. 1). These outcomes are discussed in detail below.

Sepsis
Neonatal complications of chorioamnionitis include congenital sepsis and infections such as pneumonia, dermatitis, and otitis media.[20,85–88] In a recent meta-analysis, histological chorioamnionitis was associated with confirmed and any early-onset neonatal sepsis (unadjusted pooled odds ratios (ORs) 4.42 [95% confidence interval (CI) 2.68–7.29] and 5.88 [95% CI 3.68–9.41], respectively). Clinical chorioamnionitis was also associated with confirmed and any early-onset neonatal sepsis (unadjusted pooled ORs 6.82 [95% CI 4.93–9.45] and 3.90 [95% CI 2.74–5.55], respectively). Additionally, histologic and clinical chorioamnionitis were each associated with higher odds of late-onset sepsis in preterm neonates.[79]

In a large multicenter study, prospective surveillance for early-onset neonatal infections that included about 400,000 live births 389 infants were diagnosed with early-onset sepsis, of whom 232 (60%) were exposed to clinical chorioamnionitis. In all, 96% of preterm and 72% of term infants were not well appearing. In contrast, only 29 cases (0.007%) of culture-positive infants were asymptomatic.[89] Thus, few of the infants exposed to chorioamnionitis are infected and the infected preterm infants are generally symptomatic. Implementation of current clinical guidelines likely leads to exposure of large numbers of uninfected asymptomatic infants to antibiotics.

Respiratory distress syndrome (RDS) and bronchopulmonary dysplasia (BPD)
In chorioamnionitis, fetal breathing leads to mixing of fetal lung fluid with amniotic fluid resulting in potential lung exposure. Initial studies showed that ventilated preterm infants exposed to histologic chorioamnionitis had less RDS but more BPD than infants not exposed to chorioamnionitis.[90] Preterm infants exposed to histologic chorioamnionitis had decreased incidence of RDS, but histologic chorioamnionitis with isolation of Ureaplasma or Mycoplasma from cord blood did not correlate with a decreased risk of RDS.[26] Prenatal exposure to high levels of tumor necrosis factor-α in amniotic fluid as seen in chorioamnionitis predict RDS and prolonged postnatal ventilation, suggesting early and persistent lung injury from chorioamnionitis.[91] On the contrary, Lahra et al. noticed a decreased risk of RDS and BPD in those exposed to histological chorioamnionitis.[92] Another large study in infants <28 weeks of gestation found no association between histologic chorioamnionitis, funisitis, or specific organisms and the initial oxygen requirements of the infants.[93] Chorioamnionitis can alter the response to clinical outcomes. In a study of preterm infants with RDS, exposure to severe chorioamnionitis led to a poor response to surfactant,[94] possibly by altering lung surfactant lipid profiles.[95]

A meta-analysis of 244,000 infants concluded that chorioamnionitis increased the risk of BPD.[82] However, reports from the Canadian Neonatal Network and by Laughon et al. found no association of BPD with chorioamnionitis.[85,93] It is possible that chorioamnionitis modulates the risk of having BPD by providing the first hit and the subsequent postnatal mechanical ventilation and oxygen exposure providing the second hit to develop BPD.[96] Studies show that overall BPD risk was decreased in ventilated infants with chorioamnionitis but increased in infants ventilated for >7 days or with postnatal sepsis.[97] In another study, BPD was increased threefold in infants positive for Ureaplasma or Mycoplasma.[26] Thus, lung exposures to chorioamnionitis may result in variable effects on lung maturation, ranging from increased surfactant synthesis to lung injury from inflammation, depending on the organism and the duration of exposure. Lung inflammation caused by chorioamnionitis may promote progression toward BPD by interfering with multiple signaling pathways involved in lung development.[96]
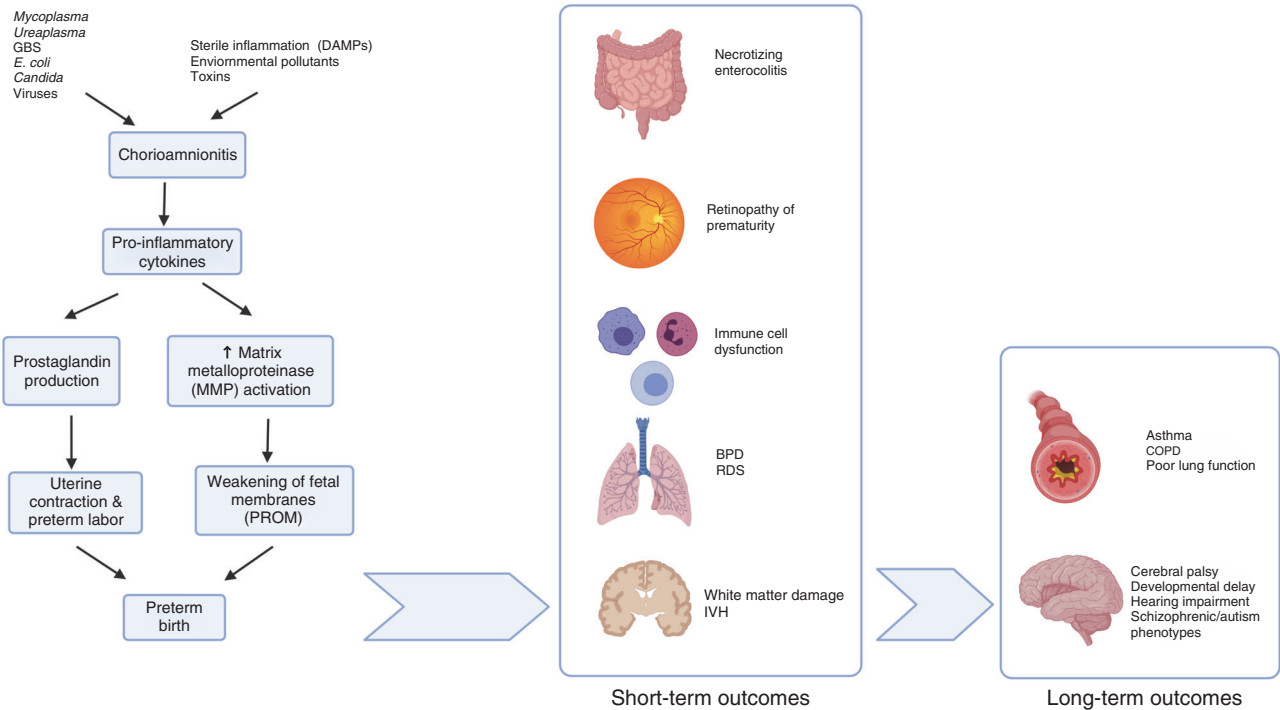
Fig. 1 Exposure to various microbes or sterile inflammation leads to chorioamnionitis and release of various pro-inflammatory cytokines, which in turn causes preterm labor and/or premature rupture of membranes (PROM). These in turn lead to various short-term and long-term chorio-mediated outcomes. DAMP damage-associated molecular patterns, BPD bronchopulmonary dysplasia, RDS respiratory distress syndrome, IVH intraventricular hemorrhage, COPD chronic obstructive pulmonary disease.

In summary, BPD is a complex lung development/injury/repair syndrome with multiple postnatal factors contributing to its occurrence and progression. Chorioamnionitis may result in early respiratory advantage to preterm infants, but this advantage may be offset by increased risk of BPD. Some chorioamnionitis exposures may protect the infant from BPD by decreasing the severity of RDS (lung maturation) while other types of exposures may promote BPD by initiating a progressive inflammatory response.

Neurodevelopment
Multiple epidemiological studies have linked perinatal brain injury such as cerebral palsy, periventricular leukomalacia, and IVH with chorioamnionitis.[98,99] Chorioamnionitis is associated with an increased incidence of speech delay and hearing loss at 18 months of corrected age in infants born very preterm.[100] Chorioamnionitis has also been linked to various schizophrenia and autism-specific phenotypes.[101]

The association between clinical and/or histological chorioamnionitis and poor neurodevelopmental outcomes or death in newborns has been debated, with multiple positive and negative studies in the literature.[83,84,102,103] This is likely due to varying definitions of chorioamnionitis and inappropriate adjustment for clinical factors that lie on the causal chain (e.g., gestational age).[104] In addition, animal models have consistently shown increased brain damage specifically in the white matter of the brain with chorioamnionitis.[105,106]

Inflammatory cytokines released during chorioamnionitis have been suggested as a possible cause of cerebral injury observed in human studies.[107–109] These ranges from the direct effect on the cerebral vasculature causing cerebral hypoperfusion and ischemia to activation of microglia causing a direct toxic effect on oligodendrocytes and myelin via microglial production of proinflammatory cytokines, neuronal loss, and impaired neuronal guidance.[110–112]

Microbiome changes
In infants with chorioamnionitis and funisitis, stool samples collected on postnatal day 7 had a relative abundance of order *Fusobacteria*, genus *Sneathia*, or family *Mycoplasmataceae*. Presence of these specific clades in fecal samples was associated with the higher risk of sepsis or death suggesting that specific alterations in the infant gastrointestinal microbiota induced by chorioamnionitis predispose to neonatal sepsis or death.[113] In another study, Enterobacteriaceae relative abundance was higher in stool samples of infants exposed to choriomamnionits.[68]

Necrotizing enterocolitis
Meta-analyses have shown that clinical chorioamnionitis is significantly associated with NEC (12 studies; $n = 22601$; OR, 1.24; 95% CI, 1.01–1.52; $P = 0.04$). In addition, histological chorioamnionitis with fetal involvement was highly associated with NEC (3 studies; $n = 1640$; OR, 3.29; 95% CI, 1.87–5.78; $P \leq 0.0001$).[114] Intrauterine exposure to inflammatory stimuli may switch innate immunity cells such as macrophages to a reactive phenotype (priming). Confronted with renewed inflammatory stimuli during labor or postnatally, such sensitized cells may exaggerate production of proinflammatory cytokines associated with NEC (two-hit hypothesis).[115]

Long-term programming—Barker hypothesis
Barker et al. coined the fetal origins of adult disease hypothesis that later became known as the developmental origin of adult disease hypothesis. The unique characteristics of the fetal origin are (1) delayed onset of the insult phenotype much later, (2) the adverse effect from fetal exposure can last a lifetime for the affected individual, and (3) there is often a genetic reprogramming resulting from the prenatal exposure.[116]

Epigenetics describes how the environment interacts with the genome to produce heritable changes resulting in phenotypic variation without altering the DNA of the genome. Epigenetic
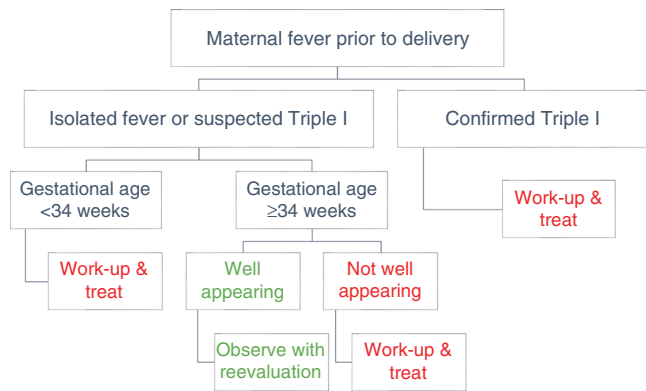
Fig. 2 Management algorithm of neonates exposed to chorioamnionitis. (Suspected Triple I is defined as fever with one or more of the following symptoms: leukocytosis, fetal tachycardia, or purulent cervical discharge. Confirmed Triple I should be accompanied by evidence of amniotic fluid infection). Adapted from Higgins et al.[6]

processes include DNA methylation, demethylation and various posttranslational processes. Studies have reported an association between DNA methylation changes of the imprinted gene PLAGL1 (pleomorphic adenoma gene-like 1—associated with abnormal development and cancer) and chorioamnionitis.[117] Other studies have found chorio-mediated tissue-specific epigenetic modifications to the genes involved in TLR signaling pathway.[118] These deleterious effects in epigenetic programming may converge to induce inflammation, impair the immune system, and cause pathologic conditions lasting well into adulthood.

In a large retrospective study of 500,000 preterm infants, chorioamnionitis increased the risk of childhood asthma.[119] Infants exposed to severe chorioamnionitis had increased cord blood IL-6 and greater pulmonary morbidity at age 6–12 months.[120] Studies in preterm infants with chorioamnionitis has found higher IL-33 in maternal serum as well as in placental membranes.[121,122] Unregulated IL-33 activity leads to activation of Th2 cells, mast cells, dendritic cells, eosinophils, and basophils, ultimately leading to increased expression of cytokines and chemokines that defines asthma disease.[123] It is possible that this increased risk of asthma is due to altered Th2 immune cell development following in utero inflammation. Thus, chorioamnionitis can potentially influence the development and maturation of the neonatal immune system. This in utero exposure to chorioamnionitis may "prime" the developing immune system, even in the absence of infection. Such a "priming" results in a more activated and mature immunophenotype, potentially increasing the susceptibility of infants to later childhood diseases, altering their response to vaccination, or contributing to the development of immunopathological disorders.[124]

MANAGEMENT
Because of the various adverse effects of chorioamnionitis as discussed above, the mere entry of chorioamnionitis in the patient's record triggers a series of investigations and management decisions in the mother and the infant, irrespective of probable cause or clinical findings. To address these wide-ranging issues, the Eunice Kennedy Shriver NICHD, Society for Maternal-Fetal Medicine, American College of Obstetricians and Gynecologists, and American Academy of Pediatrics assembled a group of maternal and neonatal experts to formulate expert opinion on the management of chorioamnionitis.[6]

The term chorioamnionitis is commonly used to denote clinical suspicion of IUI or infection even before any pathologic or laboratory evidence of infection or inflammation is uncovered. The

findings of these tests are often not conclusive and almost always not available until after the infant is delivered. In addition, the findings are also not always aligned with clinical signs. The term chorioamnionitis does not consistently convey the degree and severity of maternal or fetal illness leading to a clinical conundrum on how to appropriately treat the mother and infant. In addition, overexposure of newborns to broad-spectrum antibiotics pending exclusion of early-onset neonatal sepsis, or for "presumed" early-onset neonatal sepsis in the absence of a definitive diagnosis, has potential short- and long-term adverse effects such as higher risks of neonatal morbidity and mortality.[125]

Neonatal management of those born to chorioamnionitis
Neonatal management should be guided by the clinical category of isolated fever, suspected Triple I or confirmed Triple I, gestational age at birth, and clinical condition of the neonate (Fig. 2).[6]
Term and late preterm neonates:

1. Isolated maternal fever: Treatment is not beneficial for well-appearing term and late preterm neonates regardless of mother receiving antibiotics.
2. Suspected Triple I: Clinical condition should guide care. The majority of well-appearing term and late preterm neonates who are asymptomatic can be closely observed without antibiotics. Using the sepsis calculator may help with the decision to treat or not to treat in such cases.[126] The sepsis calculator has been able to decrease the use of antibiotics from 99.7 to 2.5% in babies exposed to chorioamnionitis.[127] However, recent meta-analyses have shown that the probability of missing early-onset sepsis is higher in babies exposed to chorioamnionitis.[128]
3. Confirmed Triple I: Neonates should be treated according to current guidelines.

Neonates born at <34 0/7 weeks of gestation

1. Isolated maternal fever: well-appearing preterm neonates can be observed if laboratory data are not favoring sepsis, but this recommendation is not evidence based.
2. Suspected or confirmed Triple I: neonates should be started on antibiotics as soon as cultures are obtained.

DURATION OF ANTIBIOTIC THERAPY
There is a paucity of studies to guide clinical practice for the duration of antibiotics when cultures are negative. In most well-appearing infants, there is no compelling evidence that antibiotics need to be continued beyond 36–48 h, especially when blood cultures are negative and regardless of how "abnormal" laboratory data are found in these newborns.[6]

FUTURE STUDIES
The gold standard used for the diagnosis of intra-amniotic infection/inflammation is amniotic fluid obtained by amniocentesis, which is not feasible in every case. Rapid point-of-care or near-patient testing to assess amniotic fluid for inflammatory markers may help identify patients with true intra-amniotic inflammation.[129,130]

In summary, chorioamnionitis exposure is common and is associated with many short- and long-term morbidity. A better understanding of microbiome alterations and inflammatory dysregulation may help develop better treatment strategies for infants born to mothers with chorioamnionitis. To optimize outcomes, it is essential to define the consequences of chorioamnionitis in preterm infants and the underlying mechanisms by

basic science and translational investigation followed by clinical research focused on important outcomes both in the NICU and in early childhood.

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COMPETING INTERESTS
The authors declare no competing interests.

ADDITIONAL INFORMATION
Correspondence and requests for materials should be addressed to V.G.J.

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