

CONTENTS

Congenital Cytomegalovirus

EDITORIAL BOARD

Editor: Delane Shingadia



David Burgner (Melbourne, Australia)

Kow-Tong Chen (Tainan, Taiwan)

Luisa Galli (Florence, Italy)

Steve Graham (Melbourne, Australia)

Cristiana Nascimento-Carvalho (Bahia, Brazil)

Ville Peltola (Turku, Finland)

Emmanuel Roilides (Thessaloniki, Greece)

Ira Shah (Mumbai, India)

Board Members

George Syrogiannopoulos (Larissa, Greece)

Tobias Tenenbaum (Mannheim, Germany)

Marc Tebruegge (Southampton, UK)

Marceline Tutu van Furth (Amsterdam, The Netherlands)

Congenital Cytomegalovirus

A European Expert Consensus Statement on Diagnosis and Management

Suzanne E. Luck, MBChB, MD,†‡ Daniel Blázquez-Gamero, MD, PhD,¶
Philipp Henneke, MD,|| Katharina Schuster, MD,|| Karina Butler, MB, BCh, FRCPI,** Maria Grazia Capretti, MD, PhD,††
Maria José Cilleruelo, PhD,‡‡ Nigel Curtis, MA, MBBS, DCH, DTM&H, MRCP, FRCPC, PhD,§§
Francesca Garofoli, PhD,¶¶ Paul Heath, MB BS, FRCPC,* Elias Iosifidis, MD, MSc, PhD,|||
Nigel Klein, BSc, MBBS, PhD,*** Giuseppina Lombardi, MD,††† Hermione Lyall, BSc Hons, MBChB, MD, FRCPC,‡‡‡
Tea Nieminen, MD, PhD,§§§ Dasja Pajkrt, MD, PhD, MBA,¶¶¶ Vassiliki Papaevangelou, MD, PhD,||||
Klara Posfay-Barbe, MD, MS,**** Laura Puhakka, MD,§§§ Emmanuel Roilides, MD, PhD, FIDSA, FAAM,|||
Pablo Rojo, MD PhD,¶ Jesús Saavedra-Lozano, MD, PhD,†††† Teshri Shah, MSc,‡‡‡ Mike Sharland, FRCPC,*
Harri Saxen, MD, PhD,§§§ and Ann C.T.M Vossen, MD, PhD,‡‡‡‡ on Behalf of the ESPID Congenital
CMV Group Meeting, Leipzig 2015*

Key Words: congenital CMV, investigation, management, treatment

Congenital cytomegalovirus (cCMV) is the most common congenital infection

in the developed world. Reported prevalence varies between cohorts but is approximately 7 per 1000 births.¹ About half of cytomegalovirus (CMV)-infected babies with clinically detectable disease at birth are destined to have significant impairments in their development, and cCMV infection is implicated in approxi-

mately 25% of all children with sensorineural hearing loss (SNHL).^{1,2} Meta-analysis shows that although long-term sequelae, especially SNHL, are more common in those with clinically detectable disease at birth, they are also found in 13% of those without clinical features attributable to CMV on initial examination.¹

Accepted for publication August 31, 2017.

From the *Paediatric Infectious Diseases Research Group, St George's University, London, United Kingdom; †Centre for Virology, University College Medical School, London; ‡Kingston Hospital NHS Foundation Trust, London, United Kingdom; §The Hague Medical Center (HMC), Department of Pediatrics and Sophia Children's hospital, Erasmus Medical Center Rotterdam Department of Pediatric Infectious Diseases; ¶Pediatric Infectious Diseases Unit, Hospital Universitario 12 de Octubre, Universidad Complutense, Instituto de Investigación Hospital 12 de Octubre, Madrid, Spain; ||Center for Chronic Immunodeficiency and Center for Pediatrics and Adolescent Medicine, Medical Center and Faculty of Medicine, University of Freiburg, Germany; **Our Lady's Children's Hospital Crumlin, Copyright © 2017 Wolters Kluwer Health, Inc. All rights reserved.

ISSN: 0891-3668/17/3612-1205

DOI: 10.1097/INF.0000000000001763

UCD School of Medicine and Health Sciences, Dublin, Ireland; ††Department of Obstetrical, Gynaecological and Paediatric Sciences, Operative Unit of Neonatology, Policlinic St. Orsola-Malpighi, University of Bologna, Bologna, Italy; ‡‡Pediatric Infectious Diseases, Hospital Universitario Puerta de Hierro Majadahonda, Madrid, Spain; §§Department of Paediatrics, The University of Melbourne & Murdoch Children's Research Institute, Royal Children's Hospital Melbourne, Parkville, Australia; ¶¶NICU and Neonatal Unit, Fondazione IRCCS Policlinico S. Matteo, Pavia, Italy; |||Infectious Diseases Unit, 3rd Department of Pediatrics, Faculty of Medicine, Aristotle University School of Health Sciences, Thessaloniki, Greece; ***Great Ormond Street Children's Hospital, London, and the Institute of Child Health, UCL, London, United Kingdom; †††NICU and Neonatal Unit, Fondazione IRCCS Policlinico S. Matteo, Pavia, Italy; ‡‡‡Imperial College NHS Healthcare, London, United Kingdom;

§§Pediatric Infectious Diseases, Children's Hospital, University of Helsinki and Helsinki University Hospital, Finland; ¶¶¶Department of Pediatric Infectious Diseases, Emma Children's Hospital, Academic Medical Center, Amsterdam, The Netherlands; |||||National and Kapodistrian University of Athens, Greece; ****Children's Hospital of Geneva, University Hospitals of Geneva, Switzerland; ††††Pediatric Infectious Diseases Unit, Gregorio Marañón Hospital, Madrid, Spain; and ‡‡‡‡Department of Medical Microbiology, Leiden University Medical Center, Leiden, The Netherlands.

Dr Luck has recently provided consultancy services to Roche.

The authors have no funding or conflicts of interest to disclose.

Address for correspondence: Suzanne E. Luck, MBChB, MD, Paediatric Infectious Diseases Research Group, St George's University, Jenner Wing, Level 2, Room 2.216F, Mail Point J2C, London, SW17 0RE. E-mail: Suzanne.luck@ucl.ac.uk.

The ESPID Reports and Reviews of *Pediatric Infectious Disease Journal* series topics, authors and contents are chosen and approved independently by the Editorial Board of ESPID.

Despite the significant long-term impact of cCMV infection, there is limited evidence on which to base many treatment decisions in clinical practice. In an era of enhanced perinatal screening, fetuses and newborns are increasingly tested for CMV after abnormalities were detected during routine ultrasonography or maternal serology. Furthermore, otherwise “asymptomatic”, congenitally CMV-infected, newborns are being identified after detection of SNHL through newborn hearing screening programs. Because of earlier diagnosis, babies with cCMV now presenting to pediatricians differ from those primarily included in clinical trials of treatment reported in the literature.

A symposium was convened during the 2015 conference of the European Society of Paediatric Infectious Diseases to discuss the current management of cCMV. In attendance were clinicians from throughout Europe, many of whom are involved in policy for cCMV for their region/country.

This article summarizes the discussions at this meeting alongside the evidence informing them. A balanced perspective of the controversies in this area is presented and areas of consensus highlighted. Finally, where evidence is lacking, suggestions are made for future research efforts to address areas of unmet medical need.

The authors acknowledge the coexisting need for studies on the management of babies with symptoms consistent with cCMV, but in whom this diagnosis cannot be firmly established, and of those with symptomatic postnatal CMV infection; this article does not, however, address these groups.

The internationally accepted GRADE system for evaluating evidence has been used to illustrate points where relevant (Table 1).³

DEFINITIONS OF SYMPTOMATIC DISEASE

Classically, cCMV infection is categorized as “symptomatic” or “asymptomatic” at birth. Differing definitions and opinions on what constitutes “symptomatic” CMV infection, however, makes interpreting the literature challenging. Indeed, some of the largest cohort studies include babies with SNHL at birth in the group described as being “asymptomatic” because no “clinically apparent disease” was detectable during newborn examination.⁴ In modern healthcare systems, whereby cCMV is increasingly detected through screening for other conditions, alongside increased accessibility of investigations, such as magnetic resonance imaging (MRI), the traditional dichotomy between clinically “apparent” and “inapparent” disease is becoming less meaningful. Table 2 summarizes the accepted clinical features of

TABLE 1. Grade System of Evaluating Evidence³

Quality Rating	Definition	Example Methodology	Depiction in Text
High	Further research is very unlikely to change our confidence in the estimate of effect	Randomized trials or double-upgraded observational studies	A
Moderate	Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate	Downgraded randomized trials or upgraded observational studies	B
Low	Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate	Double-downgraded randomized trials or observational studies.	C
Very low	Any estimate of effect is very uncertain	Triple-downgraded randomized trials, or downgraded observational studies, or case series/case reports	D

Strength of Recommendation	Definition	Depiction in Text
Strong recommendation for using (or not using) an intervention	Most informed patients would choose the recommended management and clinicians can structure their interactions with patients accordingly	1
Weak recommendation for using (or not using) an intervention	Patients' choices will vary according to their values and preferences and clinicians must ensure that patients' care is in keeping with their values and preferences	2

Strength of recommendations is determined by the balance between desirable and undesirable consequences of alternative management strategies, quality of evidence, variability in values and preferences and resource use.

TABLE 2. Possible Signs and Symptoms in Children With Congenital CMV⁵⁻⁸

Clinically detectable symptoms/signs
Physical Examination
Small for gestational age (birth weight <-2 SD for gestational age)
Microcephaly (head circumference <-2 SD for gestational age)
Petechiae or purpura (usually found within hours of birth and persist for several weeks)
Blueberry muffin rash (intra dermal hematopoiesis)
Jaundice*
Hepatomegaly
Splenomegaly
Neurologic physical examination
Microcephaly (head circumference <-2 SD for gestational age)
Neurologic signs (lethargy, hypotonia, seizures, poor sucking reflex)
Abnormalities detected incidentally or through subsequent investigation/specialist examination
Laboratory results
Anemia
Thrombocytopenia (occurs in the first week but platelets often increase spontaneously after the second week)
Leukopenia, isolated neutropenia
Elevated liver enzymes (ALT/AST)
Conjugated hyperbilirubinemia
Cerebrospinal fluid
Abnormal cerebral fluid indices, positive CMV DNA
Neuroimaging
Calcifications, periventricular cysts, ventricular dilatation, subependymal pseudocysts, germinolytic cysts, white matter abnormalities, cortical atrophy, migration disorders, cerebellar hypoplasia, lenticulostratial vasculopathy
Hearing test
Sensorineural hearing loss uni- or bilaterally
Visual examination
Chorioretinitis, retinal hemorrhage, optic atrophy, strabismus, cataracts

*CMV-associated jaundice can be present at the first day after birth and usually persists longer than physiologic jaundice.

ALT indicates alanine aminotransferase; AST, aspartate aminotransferase; SD, standard deviations.

cCMV disease with those symptoms detectable on newborn examination listed separately to those detectable only if specific investigations are conducted, for example, when cCMV is already suspected.⁵⁻⁸

Full Consensus Within This Expert Group Was That

1. For the purposes of research and publication, newborns identified as having cCMV disease after abnormal clinical examination at birth (such as microcephaly, small for gestational age (SGA), widespread petechiae, hepatosplenomegaly) should be differentiated from those babies identified through screening or investigation for other disorders, for example, those tested for CMV after known/likely maternal infection or abnormal newborn hearing screening. This differentiation would allow for more accurate assessment of the prognostic value of individual manifestations of “symptomatic” disease on longer-term outcomes as already shown in other publications.⁹
2. “Symptomatic” cCMV should be considered as “severe,” “moderate” or “mild” disease.
 - a. “Mild” disease includes those with isolated (1 or 2 at most), otherwise, clinically insignificant or transient findings, such as petechiae, mild hepatomegaly or splenomegaly or biochemical/hematologic abnormalities (such as thrombocytopenia, anemia, leukopenia, borderline raised liver enzyme abnormalities or conjugated hyperbilirubinemia) or SGA (defined as weight for gestational age <-2 standard deviations) without microcephaly.
 - b. “Severe” disease includes those with central nervous system (CNS) involvement (abnormal neurologic or ophthalmologic examination, microcephaly or neuroimaging consistent with cCMV disease [such as calcifications, moderate to severe ventriculomegaly, cysts, white matter changes, cerebral or cerebellar hypoplasia, hippocampal dysplasia, neuronal migration abnormalities])¹⁰ or with life-threatening disease.

The Majority Agreed That

- 2b. “Severe” disease also includes babies with evidence of severe single-organ disease (including those with clinically significant liver enzyme abnormalities [liver “failure”] and marked hepatosplenomegaly) or those with significant

multiorgan involvement. Babies with transient or otherwise clinically insignificant abnormalities (ie, the babies are not “sick”) that resolve spontaneously over a few weeks are not included in this group even if these abnormalities are multiple.

- 2c. A further group exists that may be considered to have “moderate” disease. This group is heterogeneous and includes, for example, those with persistent (eg, more than 2 weeks duration) abnormalities of hematologic/biochemical indices or more than 2 “mild” disease manifestations (as listed earlier). Because of lack of evidence, full consensus could not be reached on how to approach this group, and treatment decisions are currently made on a case by case basis. Development of a validated clinical scoring system for disease severity at presentation and risk of sequelae would be beneficial for both counseling parents and informing treatment decisions.
3. Defining CNS involvement
 - a. It remains uncertain whether some, nonspecific findings detected on cranial ultrasound (CrUSS) and MRI (particularly isolated lenticulostriatal vasculopathy [LSV]) constitute clinically significant CNS disease. LSV has been detected in 0.4%–5.8% of all neonates undergoing an ultrasound, and only 5% has been associated with cCMV.^{11,12} Some have suggested isolated LSV as a marker of risk for SNHL.¹¹ Others have found only more extensive neuroimaging abnormalities to be of prognostic value.^{13,14} The majority at this meeting would not consider LSV in isolation to be a notable CNS manifestation of disease. It is suggested that neuroradiologic abnormalities not known to be clearly associated with CMV disease and adverse outcomes are discussed with a suitably experienced neuroradiologist, particularly, if the results of these discussions might influence treatment decisions.
 - b. The exact pathophysiology of SNHL is not clear but is likely secondary to infection and degradation of sensory structures within the inner ear.^{15,16} It is therefore debated whether isolated SNHL should truly be considered a CNS manifestation of infection and, as a consequence, whether such children should be considered comparable to those with CNS disease included in published clinical trials. No studies have

addressed this specific population, but a nonrandomized cohort study observing the effects of valganciclovir in isolated SNHL is in progress (clinicaltrials.gov NCT02005822). The majority of experts at this meeting would categorize babies with isolated, confirmed SNHL in the “severe”/CNS group because bilateral SNHL is not only associated with likely long-term impairments but was also included in the criteria for recruitment in the only randomized controlled trials (RCTs) in cCMV. However, consensus was not reached because the spectrum of hearing loss is wide, and treatment of isolated SNHL has not been evaluated in any RCTs.

WHEN SHOULD TESTING FOR CONGENITAL CMV BE CONSIDERED?

Indications for testing for cCMV are based on the presence of one or more of the most frequently observed clinical features (Table 3).¹⁷ Unfortunately, predictive values for each of these features are not available.

Full Consensus Within This Expert Group Was That Testing for cCMV Should be Performed in

1. Fetuses with ultrasound/MRI imaging consistent with cCMV disease (by appropriately timed antenatal testing of amniotic fluid).¹⁸ (Quality C, Level 1)
2. Newborns where there is a maternal history of suspected primary CMV infection during pregnancy. If antenatal testing of amniotic fluid has been conducted, it is suggested that cCMV infection should still be confirmed at birth because both false-positive and -negative results have been reported.¹⁸ (Quality C, Level 1)
3. Newborns with signs/symptoms consistent with cCMV disease (see Table 2; including those with findings consistent with cCMV on antenatal imaging). (Quality B, Strength 1)
4. Children with confirmed SNHL.¹⁶ Systems need to be established to ensure testing for cCMV occurs, where possible, in the first 21 days of life because dried blood spot (DBS) are not always readily available for testing (see below). (Quality B, Strength 1)

The Majority Agreed That

5. Newborns who are SGA should not routinely be tested. Studies in SGA newborns have shown the prevalence of cCMV to be 0%–5.2%.¹⁹⁻²² However, the majority of

TABLE 3. Clinical Features That Should Lead to Testing for Congenital CMV

Neonates
Physical examination
Hepatosplenomegaly
Petechiae, purpura or blueberry muffin rash in a newborn
Jaundice (prolonged or conjugated hyperbilirubinemia)
Microcephaly (head circumference <-2 SD for gestational age)
<i>Consider if symmetrically small for gestational age (<-2 SD for gestational age)</i>
Neurology
Seizures with no other explanation
Laboratory parameters
Prolonged jaundice with transaminitis
Conjugated hyperbilirubinemia
Unexplained thrombocytopenia, consider if leucopenia or anemia
Neuroimaging
Intracranial calcification (often periventricular)
Intracranial ventriculomegaly without other explanation
<i>Consider in the case of periventricular cysts, subependymal pseudocysts, germinolytic cysts, white matter abnormalities, cortical atrophy, migration disorders, cerebellar hypoplasia, lenticulostriate vasculopathy</i>
Visual examination
Abnormal findings on ophthalmologic examination consistent with congenital CMV (eg, chorioretinitis)
<i>Consider if congenital cataracts</i>
Failed neonatal hearing screen
Maternal serology
Evidence of maternal seroconversion*
<i>Consider in women with known CMV infection (known IgG seropositive at start of pregnancy), particularly, if symptoms or virologic examination consistent with suspected CMV reactivation/reinfection*</i>
<i>Prematurity†</i>
Older children
Sensorineural hearing loss: new diagnosis

Features in bold are those where there is consensus for testing. Features in italics are those that might lead to testing in individual circumstances and depending on local practice.

*Seek expert clinical virology advice for interpretation of virologic investigations in pregnancy.

†Baseline screening to differentiate between congenital and postnatal CMV infection is helpful for extremely premature infants (<28 weeks gestational age) who are at increased risk of symptomatic postnatal infection.

SD indicates standard deviations.

studies report a prevalence of 1.4%–1.8%, which is not significantly higher than the prevalence of cCMV in the general population. Therefore, evidence is insufficient to justify screening all newborns with isolated SGA for cCMV. None of these studies distinguish between asymmetrical (with normal head circumference) and symmetrical SGA, but when head circumference was mentioned, most SGA babies with cCMV had microcephaly (head circumference <-2 standard deviations).^{21,22} Because of this, and the poor prognostic outcome of children with cCMV and microcephaly, many present at this meeting test those babies with symmetrical SGA but not those with preserved head growth.¹⁴(Quality C, Strength 2)

6. Prematurity. Evidence that premature babies have a higher incidence of cCMV is limited.^{20,23} Testing extremely premature babies (<28 weeks gestational age) at birth does, however, assist in differentiating between congenital and postnatal infection. This may be very helpful in guiding the management of these babies that are particularly vulnerable to symptomatic postnatal infection. However, consensus

was not reached regarding practice in this area, with cost being a factor among other considerations.²⁴ (Quality C, Strength 2)

7. Testing of babies born to mothers who are known to be CMV seropositive at the establishment of pregnancy. Although maternal nonprimary CMV infection is known to be important when considering the overall burden of cCMV disease, testing all babies born to these women, particularly in populations with high maternal seroprevalence, is tantamount to universal neonatal screening.^{25,26} Identifying women with nonprimary CMV who are at highest risk of transmitting infection to their fetus remains elusive. It was agreed that individual case discussion and local policy should therefore dictate practice in this area. Further research is clearly needed.

LABORATORY DIAGNOSIS OF CONGENITAL CMV INFECTION

Testing for cCMV using CMV polymerase chain reaction (PCR) in urine is highly reliable: sensitivity is 100% and specificity 99%.²⁷ One negative urine specimen in a neonate is therefore sufficient to exclude

infection, and repeat sampling is not necessary. After 21 days, a urine positive for CMV could be because of CMV acquired postnatally from, for example, passage through the birth canal or through breast milk. As CMV PCR techniques are becoming more sensitive, earlier testing, before the age of 14 days, is recommended.²⁷

CMV PCR testing of saliva is an alternative and is easy to perform. Samples should be taken immediately before feeding in breastfed newborns, and confirmed with urine, as false-positive results have been reported.^{28–31}

PCR assay of neonatal DBS can be performed retrospectively in an attempt to diagnose cCMV after the first 21 days of life. Sensitivity is around 84% in meta-analysis but is highly variable depending on the laboratory techniques used and the population being tested; a negative DBS PCR cannot, therefore, be used to definitively exclude a diagnosis of cCMV.³²

Full Consensus Within This Expert Group Was That

1. Testing for cCMV should be performed using a single CMV PCR of urine obtained within 21 days of birth but ideally within 14 days of birth (Quality B, Strength 1).
2. Saliva PCR testing can be an alternative, but a positive result should be confirmed using urine (Quality B, Strength 1).
3. After the age of 21 days, CMV DNA PCR of stored DBS can be used to diagnose cCMV retrospectively; sensitivity is relatively low, and a negative test cannot be used to definitively exclude a diagnosis of cCMV (Quality B, Strength 1).

RECOMMENDED INVESTIGATIONS AFTER CONFIRMING A DIAGNOSIS OF CONGENITAL CMV INFECTION

After a virologic diagnosis of cCMV infection has been made, additional investigations are necessary to evaluate the extent of disease and to assist with discussions regarding prognosis and treatment.

Full Consensus Within This Expert Group Was That

1. The investigations below are conducted in any baby in whom a diagnosis of cCMV is confirmed, looking specifically for the manifestations of disease (Table 2):
 - Complete blood count, liver enzymes, (conjugated) bilirubin
 - Renal function (before initiating therapy)

- CrUSS. (Quality A, Strength 1)
 - Audiologic testing (brainstem-evoked response; some screening tests such as otoacoustic emissions are not sufficient to detect central auditory hearing loss in cCMV). (Quality A, Strength 1)
 - Ophthalmic assessment. (Quality A, Strength 1)
2. If additional imaging to CrUSS is felt to be indicated, then MRI is the preferred neuroimaging modality. MRI can be successfully performed in neonates without the need for sedation and is, therefore, both highly sensitive and free of the risks of radiologic exposure, which accompany computed tomography. (Quality C, Strength 1)
 3. MRI should be performed in babies with clinically detectable neurologic findings or CrUSS abnormalities.

The Majority Agreed That

4. Cranial MRI should be performed in any babies with cCMV and evidence of CMV disease (see Table 2). (Quality C, Strength 1)
5. CMV PCR quantitation should be performed in blood at baseline. Several studies have shown the absence of CMV viremia to be associated with better long-term outcomes, and this may be reassuring when evaluating babies without any other manifestations of cCMV disease.^{33–35} Blood CMV PCR should not, however, be used to rule out cCMV infection because, paradoxically, the absence of CMV in blood has been described even in babies with severe cCMV disease.^{33,36} (Quality C, Strength 2)
6. Examination of cerebrospinal fluid (CSF): No current evidence supports examination of CSF as part of routine diagnostic work up. Studies have shown detectable CMV DNA in CSF, and elevated biomarkers such as β 2-microglobulin suggest a poor prognosis.^{13,37} However, others have shown no additional prognostic value from CSF specimens obtained in the clinical setting.³⁷ Despite this lack of evidence, there was a majority view that although a possible area of interest for future research, lumbar puncture should not be performed routinely in babies with cCMV infection (Quality C, Strength 1).

Only a Minority Agreed That

7. Cranial MRI should be performed in all CMV-infected babies. Although there is no conclusive evidence that performing MRI gives additional prognostic information to CrUSS in those without evidence

of CMV disease at birth, some argued that it is desirable to conduct MRI in all cCMV-infected babies because additional pathology can be identified as compared with CrUSS^{38–40} (Quality D, Strength 2).

TREATMENT

No antiviral drugs are currently licensed for the treatment of cCMV. Although many case reports and cohort studies have reported on treatment for cCMV, there are results from only 2 RCTs.^{7,41–44} The first of these studies evaluated 6 weeks' intravenous ganciclovir treatment in neonates (<1 month of age), gestational age \geq 32 weeks and clinically apparent disease in the newborn period with evidence of CNS disease (including microcephaly, intracranial calcification, abnormal CSF indices for age, hearing deficit and chorioretinitis).⁷ Improved hearing and neurodevelopmental outcomes were shown, but there was significant loss to follow-up.^{7,44} A more recent trial compared 6-week to 6-month treatment with oral valganciclovir and included babies with any evidence of symptomatic (including non-CNS) cCMV disease.⁴¹ Few babies enrolled, however, had isolated, mild clinical features, and none in the 6-month treatment group had isolated SNHL (D Kimberlin 2015, personal email correspondence, 28 April). A modest benefit on both 2-year hearing and neurodevelopmental outcomes was shown with the 6-month treatment course. The longer treatment course improved likelihood of better hearing outcomes most notably in those with preexisting CNS involvement. Longer duration of therapy was only statistically significant, however, for "total ear" hearing as opposed to "best ear" hearing (which is of greater functional significance) and only once adjusted for baseline CNS involvement. Given the natural resolution of some features of cCMV disease in published cohorts, alongside the delayed onset of hearing loss and fluctuations in SNHL reported in cCMV, it is even more challenging to draw any conclusions regarding treatment effect from uncontrolled studies.^{7,16,45}

Clinical trials to date do not, therefore, provide good evidence on which to base treatment decisions for many of the infants presenting to clinicians in everyday clinical practice.

Table 4 provides guidance on which infants should be offered treatment after a risk versus benefit discussion with the family. This table and associated text indicate areas where consensus was reached. Much discussion focused around the treatment of babies with less severe cCMV disease and whether the minimal additional benefit shown in the 6-month treatment course was sufficient to justify such a prolonged course of treatment.

Although clinical findings such as SGA and petechiae have been shown in historical cohorts to predict risk for SNHL, more recent reanalysis of data indicates that these findings in isolation are generally associated with disease-free outcomes in babies presenting without other manifestations of symptomatic disease.^{9,46} Opinion on the severity, or number, of symptoms justifying antiviral treatment remains divided, and it is therefore strongly recommended that clinicians discuss treatment initiation and duration with an expert in this area.

Full Consensus Within This Expert Group Was That

1. Babies with evidence of CNS disease should receive antiviral treatment (Quality A, Strength 1). Treatment should be preferably for 6-months duration (Quality B, Strength 2).
2. Babies with no clinical/laboratory findings consistent with CMV disease should not receive treatment because no evidence exists to support treatment in this group (Quality D, Strength 1 [not to treat]).
3. Babies with evidence of life-threatening disease or severe single-organ disease or multiorgan involvement should receive treatment. Although evidence is limited, particularly for life-threatening disease, consensus was that treatment should be considered in this group (Quality B, Strength 1). Consensus could not be reached on duration of treatment in this group.
4. Oral valganciclovir is now the drug of choice. Intravenous ganciclovir should be used in babies unable to tolerate oral drug or where gastrointestinal absorption is uncertain (Quality A, Strength 1).

The Majority Agreed That

5. Babies with "mild" cCMV disease (as defined earlier) should not receive treatment. No studies have clearly addressed treatment in this group. Most present at this meeting would not, therefore, treat babies with 1 or 2 isolated or transient, clinically insignificant, manifestations of disease (Quality C, Strength 2).
6. Babies with "moderate" cCMV disease (as defined earlier). Evidence for treating babies with multiple, but not severe, manifestations of disease (including jaundice, hepatosplenomegaly without significantly raised liver enzymes, SGA) is limited. It is, therefore, recommended that these cases are discussed on a case-by-case basis with a clinician with experience of managing babies with cCMV (such as a pediatric infectious disease specialist) (Quality B, Strength 2).

TABLE 4. Summary of Treatment Recommendations

Disease Manifestation	Treatment Recommendation	Level of Evidence
Consensus		
CNS disease	Ganciclovir/valganciclovir: duration 6 months*	Treatment: Quality A, Strength 1 (to treat) Duration: Quality B, Strength 2
Microcephaly, CNS calcification, chorioretinitis White matter changes (or other abnormalities on MRI consistent with CMV disease)†		
Other “severe” disease (includes life-threatening or severe single-organ or multiorgan non-CNS disease)	Ganciclovir/valganciclovir: minimum of 6 weeks, up to 6 months*‡	Treatment: Quality B, Strength 1 Duration: Quality B, Strength 2
“Mild” disease: isolated or transient disease (eg, jaundice, Petechiae, SGA in isolation; max 2 abnormalities)	No treatment	Treatment: Quality C, Strength 2 (for no treatment)
No clinical or biochemical findings of disease (± detectable CMV viremia)	No treatment	Treatment: Quality D, Strength 1 (for no treatment)
Majority opinion: but not consensus		
Isolated hearing deficit*§	Ganciclovir/valganciclovir: Duration 6 months*	Treatment: Quality C, Strength 1 Duration: Quality C, Strength 2
“Moderate” disease (see text for definition; eg, multiple minor findings consistent with CMV disease)*	Consider treatment after discussion with specialist Duration: Minimum of 6 weeks and up to 6 months*	Treatment: Quality C, Strength 2 Duration: Quality B, Strength 2

There is currently only evidence for starting treatment in the first month of life.

*Limited evidence without full consensus: see text for further description.

†In the case of isolated, nonspecific MRI findings that are not consistent with cCMV disease, it was agreed that treatment is not necessarily indicated.

‡It was suggested (without consensus) that treatment might continue in this group until the underlying clinical manifestation of disease (eg, hepatitis) resolved because benefit of 6 months treatment is unclear.

§No studies address this particular group, although they were included in eligibility criteria for treatment in both published RCTs of treatment.

- Treatment of isolated SNHL: The majority at this meeting would include SNHL at birth in their indications for treatment because this was in the inclusion criteria for treatment in previous RCTs. Furthermore, the main benefit of treatment is in preserving hearing rather than improving hearing once damage exists, with good outcomes reported in observational studies (with likely bias).^{7,41,47} There was not, however, consensus, and it is acknowledged that no RCTs have specifically addressed treatment effect in this group of babies who are usually now identified through newborn hearing screening programs (Grade C, Strength 1).
- Drug dose and formulation: Although oral valganciclovir is now first-line treatment in most cases, it is currently unknown whether valganciclovir reaches target areas as effectively as ganciclovir or, indeed, where drug should be targeted (eg, CNS or inner ear) because no studies have directly compared the 2 drugs. In those with severe disease, particularly if absorption is uncertain, intravenous ganciclovir is, therefore, preferred by some in early stages of treatment until oral therapy can be reliably tolerated (Quality C, Strength 1).
- Treatment duration in cases without CNS involvement: In those infants in whom the decision is taken to give antiviral treatment, the majority would treat for 6 months. However, there was no consensus on this point in light of the modest benefit shown for longer treatment courses in the only RCT (Quality B, Strength 2).

- Treating babies older than 28 days: Treatment of older children has not been addressed in any RCTs, although it is acknowledged that the 28-day cutoff is also not evidence based. Retrospective case series of small numbers of babies treated outside the newborn period have reported good outcomes.^{48,49} Babies found to have SNHL after hearing screening at birth often do not have a diagnosis of cCMV confirmed until outside the 1-month “window of evidence” for treatment. No consensus was reached on how late it might be acceptable to start treatment in this scenario, or in the eventuality of hearing deterioration. Two RCTs are currently evaluating the use of treatment in older children with cCMV and SNHL (clinicaltrials.gov NCT01649869 and NCT02606266), which may clarify this debate. (Evidence for treating outside the newborn period Quality D, Strength 2.)

SIDE EFFECTS OF ANTIVIRAL TREATMENT

Much of the debate around treating less severely affected babies relates to the potential side effects of currently available antiviral drugs.

Significant neutropenia is frequently observed during antiviral treatment in infants. This is reported less commonly with valganciclovir than with ganciclovir (21% compared with 65%).^{7,41,44,50} Neutropenia generally occurs during the first month of treatment, with no increased toxicity observed after 6 weeks in those randomized to receive 6-month treatment

compared with placebo in the only RCT evaluating this.⁴¹ The oral administration of valganciclovir also removes the burden of hospitalization and risk of nosocomial infections and central line complications observed during treatment with ganciclovir. Hepatotoxicity has been reported in up to 30% of those treated with ganciclovir and thrombocytopenia in a similar proportion.⁵¹ In the most recent study of treatment with valganciclovir, deranged liver function was observed, but this was neither clinically nor statistically significant when compared with placebo. In all studies, abnormal biochemical and hematologic parameters resolved after drug discontinuation.

Long-term side effects have not been evaluated in neonates treated with ganciclovir or valganciclovir. Animal studies raise the theoretical risk of gonadotoxicity and carcinogenicity.^{52,53} Although this has not been observed in humans to date, parents should be counseled about these potential risks, particularly when considering treatment in those groups in which benefit has not been clearly shown. No adverse long-term effects have been documented in a small cohort of babies treated in early neonatal studies and followed up to puberty (NCT00031421, unpublished data).

MONITORING OF BABIES DURING TREATMENT

Table 5 summarizes a proposed monitoring strategy for babies treated for cCMV. These recommendations are based on the safety monitoring and data obtained from the published RCTs.^{7,41}

TABLE 5. Monitoring and Follow-Up According to Treatment Status

No Treatment Given	Treatment Given
—	Investigations whilst on treatment*
—	FBC,* LFT† and U&E suggested weekly for first 4 weeks and then at least monthly until completion of treatment course (ganciclovir/valganciclovir)‡ (Quality B, Strength 2)
—	Weight measurement and drug dose review at time of blood sampling
—	Viral load at baseline (Quality C, Strength 2).
—	Consider Viral load 2–4 weekly whilst on antiviral therapy (not consensus; Quality D, Strength 2)§
—	Consider therapeutic drug monitoring if: Viral load increase >1.0 log ₁₀ during treatment¶ Toxicity is suspected There is an increased risk of toxicity: eg, prematurity <36 weeks, abnormal renal function (Quality D, Strength 2)
Follow up	Follow up
Audiology assessment every 3–6 months in the first year, then every 6 months until 3 years of age and then every 12 months until 6 years old (Quality C, Strength 1)	
Pediatric infectious disease clinic review (or general pediatric clinic after consultation with a specialist) until at least 1 year, and ideally 2 years, of life. (Quality D, Strength 1)	Pediatric infectious disease clinic as soon as possible in the first month, then annual review until at least age 2 years (specialist or general clinic with pediatric infectious diseases input depending on local agreements). (Quality D, Strength 1)
Monitor development. (Quality D, Strength 1)	Monitor development with neurodevelopmental assessment at 1 year in a child development service. (Quality D, Strength 1)
Ophthalmic assessment as directed by ophthalmologist, but baseline and annual review up to age 5 years in those with clinically detectable symptoms/signs at birth recommended.** (Quality D, Strength 2)	Ophthalmic assessment directed by ophthalmologist, but baseline and annual review up to age 5 years recommended.** (Quality D, Strength 2)

FBC indicates full blood count; LFT, liver function tests; U&E, urea, creatinine and electrolytes.

*Interrupt treatment or consider granulocyte colony stimulating factor (G-CSF) if absolute neutrophil count <0.5 × 10⁹/L. Decreasing dose may be considered for less severe neutropenia.

†LFT monitoring monthly is sufficient if sampling difficulties.

‡Increase frequency or seek advice if there is deterioration.

§Measuring viral load is not evidence based but offers some evaluation of virus response and enables detection of possible viral resistance.

¶Consider CMV resistance testing (sequencing) in unexplained elevations/breakthrough of viremia.

||According to current United Kingdom newborn hearing screening guidelines.

**There is limited evidence on late ocular manifestations of cCMV. They are rare and include visual impairment and strabismus.^{6,53}

There are no data to support therapeutic drug monitoring.⁵⁴ Therapeutic drug monitoring may, however, have a role when toxicity is a concern (eg, in those with impaired renal function) or where there are concerns about treatment response.

Full Consensus Within This Expert Group Was That

1. Where treatment is given, babies should have regular weight measurement and safety monitoring to enable appropriate dose adjustment of medication (see Table 5). (Quality A, Strength 1)
2. Where treatment is given, parents should be fully counseled about both the known and potential side effects of treatment with current antivirals. (Quality A, Strength 1 for short-term side effects; Long-term, no published studies)
3. Although there are theoretical risks of longer term treatment toxicity, no large cohorts have been followed up to enable this to be fully evaluated in humans treated during early life. Where possible, children receiving antiviral treatment should, therefore, be entered into a registry to enable ongoing pharmacovigilance.

Only a Minority Agreed That

1. Viral load monitoring: Some centers report monitoring viral load to assist in decisions regarding adequate drug dosing and detection of potential drug resistance; however, most experts at this meeting do not conduct this routinely. Treatment duration is not altered by any viral parameters, and rebound of virus after treatment discontinuation is well documented with no demonstrable association with long-term outcomes (Quality D, Strength 2). If viral load is checked after discontinuing drug, it is suggested that parents are forewarned of the likelihood that virus will be detectable and that this is of unknown significance.

FOLLOW-UP

Table 5 summarizes recommended follow-up of babies with cCMV (both treated and untreated).

The recommendation for audiologic follow-up is based on long-term surveillance studies of SNHL in cCMV.^{4,16} Frequent follow-up is suggested during the first 2 years of life because this is the period of highest risk

for development of cCMV-associated hearing loss and a critical period for language development. Early detection of SNHL during this period is also most likely to improve long-term outcomes.⁵⁵ Monitoring should continue into early childhood, however, because deterioration in hearing continues throughout early life⁵⁵ (Quality B, Strength 1).

Neurodevelopmental follow-up is suggested at 1 and 2 years of age ideally with formal neurodevelopmental assessment. This is not, however, routinely conducted in all centers, and there is no evidence-based benefit in this particular group, although early detection of functional impairments is generally agreed to be beneficial.

Ophthalmic follow-up is recommended annually at least until children can talk in those with clinically detectable disease at birth, but not in those without, because deterioration in vision has been observed in this group (Quality C, Strength 1).⁶

Families should be given information for local/national support groups where these exist (see acknowledgements). Where cCMV parent groups are not easily accessible, parents of children with hearing loss may find support from groups for those with hearing impairment.

RECOMMENDATIONS FOR FUTURE PEDIATRIC RESEARCH

1. Clinical trials addressing treatment of those with more “minor” manifestations of disease/no clinically detectable disease at birth and those with isolated SNHL.
2. Clinical studies of antenatal therapies to decrease transmission of infection and cCMV disease once infection is established.
3. Publications relating to cCMV should make it clear how those included were identified (ie, babies presenting with clinically detected “symptoms” vs “screened” babies identified through existing antenatal or postnatal screening pathways including hearing screening programs), or after further investigation of abnormalities, such as thrombocytopenia, found incidentally when blood sampling is performed for other indications.
4. Development of clinical prediction models to better categorize severity of disease (CNS vs non-CNS and babies with single vs multiple findings of disease) and associated outcomes to assist counseling of parents.
5. Studies of neuroimaging, particularly MRI, and added value with regards to predicting long-term impairments particularly in those without clinically detectable disease at birth through studies involving unselected cCMV cohorts.
6. Clinical trials of alternative treatment durations and new anti-CMV therapies when available.
7. Biomarkers. It seems unlikely that a pre-defined duration of treatment will be similarly beneficial in babies with such varying clinical manifestations of disease and likely variable viral burden and host immune function. The development of both host and virologic biomarkers of long-term outcomes would greatly enhance design of future RCTs and enable more accurate counseling and resource allocation.
8. All children receiving treatment should be captured in a registry to enable ongoing pharmacovigilance for any long-term effects of antiviral medication.
9. Identification of risk factors for maternal virus transmission, particularly, in those mothers with previous known exposure to CMV (CMV IgG seropositive).

CONCLUSIONS

As stated at the outset, this article represents the consensus opinion of a group of professionals with a particular interest in cCMV. It highlights that much of our practice is based on limited data but identifies areas where there is nonetheless consensus amongst experts.

Recent publications have shown potential cost effectiveness of screening at birth for cCMV, although these calculations are constrained by the issues raised in this article regarding true quantification of benefits of treatment and agreed treatment duration in certain patient groups.^{56,57} It will be challenging to address many of the research questions raised through RCTs, given the significant resources and long-term follow-up required alongside potential difficulties in recruiting into such studies when treatment is anecdotally being offered more freely. Collecting accurate data on disease manifestations and treatment outcomes in different patient groups alongside maternal demographics can, however, inform treatment strategies as previously shown very effectively for the management of pediatric human immunodeficiency virus. This requires a unified approach to initial diagnostic tests, definitions of symptomatology and follow-up which is currently being addressed by a network of clinicians with an interest in this area through both national and European initiatives such as Paediatric European Network for Treatment of AIDS - Infectious Diseases, the European Congenital CMV Initiative and European Society of Paediatric Infectious Diseases and European Society for Clinical Virology (ESCV). It should also be reiterated that this article focuses on postnatal aspects of diagnosis and treatment. There is an associated and simultaneous need for work alongside obstetric and fetal medicine colleagues to address similar uncertainties in aspects of antenatal care. It is hoped that through such collaborations, progress will be made in decreasing infection and disease in fetuses, newborns and subsequently older children with cCMV.

ACKNOWLEDGMENTS

The CMV-infected children and their parents/carers who we have cared for and who challenge us on a daily basis to provide evidence-based and consistent care including those parents who are involved with supporting other parents through local or national support groups including (but not exclusively) CMVAction (www.cmvaction.org.uk); <https://www.stopcitomegalovirus.org>.

REFERENCES

1. Dollard SC, Grosse SD, Ross DS. New estimates of the prevalence of neurological and sensory sequelae and mortality associated with congenital cytomegalovirus infection. *Rev Med Virol*. 2007;17:355–363.
2. Morton CC, Nance WE. Newborn hearing screening—a silent revolution. *N Engl J Med*. 2006;354:2151–2164.
3. Guyatt GH, Oxman AD, Vist GE, et al.; GRADE Working Group. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. *BMJ*. 2008;336:924–926.
4. Fowler KB, Dahle AJ, Boppana SB, et al. Newborn hearing screening: will children with hearing loss

caused by congenital cytomegalovirus infection be missed? *J Pediatr*. 1999;135:60–64.

5. Boppana SB, Pass RF, Britt WJ, et al. Symptomatic congenital cytomegalovirus infection: neonatal morbidity and mortality. *Pediatr Infect Dis J*. 1992;11:93–99.
6. Coats DK, Demmler GJ, Paysse EA, et al. Ophthalmologic findings in children with congenital cytomegalovirus infection. *J AAPOS*. 2000;4:110–116.
7. Kimberlin DW, Lin CY, Sánchez PJ, et al.; National Institute of Allergy and Infectious Diseases Collaborative Antiviral Study Group. Effect of ganciclovir therapy on hearing in symptomatic congenital cytomegalovirus disease involving the central nervous system: a randomized, controlled trial. *J Pediatr*. 2003;143:16–25.
8. Nassetta L, Kimberlin D, Whitley R. Treatment of congenital cytomegalovirus infection: implications for future therapeutic strategies. *J Antimicrob Chemother*. 2009;63:862–867.
9. Dreher AM, Arora N, Fowler KB, et al. Spectrum of disease and outcome in children with symptomatic congenital cytomegalovirus infection. *J Pediatr*. 2014;164:855–859.
10. Ancora G, Lanari M, Lazzarotto T, et al. Cranial ultrasound scanning and prediction of outcome in newborns with congenital cytomegalovirus infection. *J Pediatr*. 2007;150:157–161.
11. Amir J, Schwarz M, Levy I, et al. Is lenticulostriated vasculopathy a sign of central nervous system insult in infants with congenital CMV infection? *Arch Dis Child*. 2011;96:846–850.
12. de Jong EP, Lopriore E, Vossen AC, et al. Is routine TORCH screening warranted in neonates with lenticulostriate vasculopathy? *Neonatology*. 2010;97:274–278.
13. Alarcon A, Martinez-Biarge M, Cabañas F, et al. Clinical, biochemical, and neuroimaging findings predict long-term neurodevelopmental outcome in symptomatic congenital cytomegalovirus infection. *J Pediatr*. 2013;163:828–34.e1.
14. Noyola DE, Demmler GJ, Nelson CT, et al.; Houston Congenital CMV Longitudinal Study Group. Early predictors of neurodevelopmental outcome in symptomatic congenital cytomegalovirus infection. *J Pediatr*. 2001;138:325–331.
15. Gabrielli L, Bonasoni MP, Santini D, et al. Human fetal inner ear involvement in congenital cytomegalovirus infection. *Acta Neuropathol Commun*. 2013;1:63.
16. Goderis J, De Leenheer E, Smets K, et al. Hearing loss and congenital CMV infection: a systematic review. *Pediatrics*. 2014;134:972–982.
17. Jones CA. Congenital cytomegalovirus infection. *Curr Probl Pediatr Adolesc Health Care*. 2003;33:70–93.
18. Benoist G, Leruez-Ville M, Magny JF, et al. Management of pregnancies with confirmed cytomegalovirus fetal infection. *Fetal Diagn Ther*. 2013;33:203–214.
19. Khan NA, Kazzi SN. Yield and costs of screening growth-retarded infants for torch infections. *Am J Perinatol*. 2000;17:131–135.
20. Lorenzoni F, Lunardi S, Liembruno A, et al. Neonatal screening for congenital cytomegalovirus infection in preterm and small for gestational age infants. *J Matern Fetal Neonatal Med*. 2014;27:1589–1593.
21. van der Weiden S, de Jong EP, Te Pas AB, et al. Is routine TORCH screening and urine CMV culture warranted in small for gestational age neonates? *Early Hum Dev*. 2011;87:103–107.

22. Vaudry W, Rosyehuk RJ, Lee BE, et al. Congenital cytomegalovirus infection in high-risk Canadian infants: report of a pilot screening study. *Can J Infect Dis Med Microbiol.* 2010;21:e12–e19.
23. Turner KM, Lee HC, Boppana SB, et al. Incidence and impact of CMV infection in very low birth weight infants. *Pediatrics.* 2014;133:e609–e615.
24. Luck S, Sharland M. Postnatal cytomegalovirus: innocent bystander or hidden problem? *Arch Dis Child Fetal Neonatal Ed* 2009; 94(1):F58–F64.
25. de Vries JJ, van Zwet EW, Dekker FW, et al. The apparent paradox of maternal seropositivity as a risk factor for congenital cytomegalovirus infection: a population-based prediction model. *Rev Med Virol.* 2013;23:241–249.
26. Wang C, Zhang X, Bialek S, et al. Attribution of congenital cytomegalovirus infection to primary versus non-primary maternal infection. *Clin Infect Dis.* 2011;52:e11–e13.
27. de Vries JJ, van der Eijk AA, Wolthers KC, et al. Real-time PCR versus viral culture on urine as a gold standard in the diagnosis of congenital cytomegalovirus infection. *J Clin Virol.* 2012;53:167–170.
28. Boppana SB, Ross SA, Shimamura M, et al.; National Institute on Deafness and Other Communication Disorders CHIMES Study. Saliva polymerase-chain-reaction assay for cytomegalovirus screening in newborns. *N Engl J Med.* 2011;364:2111–2118.
29. Koyano S, Inoue N, Nagamori T, Moriuchi H, Azuma H. Newborn screening of congenital cytomegalovirus infection using saliva can be influenced by breast feeding. *Arch Dis Child Fetal Neonatal Ed* 2013; 98(2):F182.
30. Ross SA, Ahmed A, Palmer AL, et al.; National Institute on Deafness and Other Communication Disorders CHIMES Study. Detection of congenital cytomegalovirus infection by real-time polymerase chain reaction analysis of saliva or urine specimens. *J Infect Dis.* 2014;210:1415–1418.
31. Yamamoto AY, Mussi-Pinhata MM, Marin LJ, et al. Is saliva as reliable as urine for detection of cytomegalovirus DNA for neonatal screening of congenital CMV infection? *J Clin Virol.* 2006;36:228–230.
32. Wang L, Xu X, Zhang H, et al. Dried blood spots PCR assays to screen congenital cytomegalovirus infection: a meta-analysis. *Virology.* 2015;12:60.
33. Bradford RD, Cloud G, Lakeman AD, et al.; National Institute of Allergy and Infectious Diseases Collaborative Antiviral Study Group. Detection of cytomegalovirus (CMV) DNA by polymerase chain reaction is associated with hearing loss in newborns with symptomatic congenital CMV infection involving the central nervous system. *J Infect Dis.* 2005;191:227–233.
34. Lanari M, Lazzarotto T, Venturi V, et al. Neonatal cytomegalovirus blood load and risk of sequelae in symptomatic and asymptomatic congenitally infected newborns. *Pediatrics.* 2006;117:e76–e83.
35. Ross SA, Novak Z, Fowler KB, et al. Cytomegalovirus blood viral load and hearing loss in young children with congenital infection. *Pediatr Infect Dis J.* 2009;28:588–592.
36. Luck SE, Emery VC, Atkinson C, et al. Compartmentalized dynamics of cytomegalovirus replication in treated congenital infection. *J Clin Virol.* 2016;82:152–158.
37. Goycochea-Valdivia WA, Baquero-Artigao F, Del Rosal T, et al.; Spanish Registry of Infants with Congenital Cytomegalovirus Infection (REDICCMV) Study Group. Cytomegalovirus DNA detection by polymerase chain reaction in cerebrospinal fluid of infants with congenital infection: associations with clinical evaluation at birth and implications for follow-up. *Clin Infect Dis.* 2017;64:1335–1342.
38. Capretti MG, Lanari M, Tani G, et al. Role of cerebral ultrasound and magnetic resonance imaging in newborns with congenital cytomegalovirus infection. *Brain Dev.* 2014;36:203–211.
39. de Vries LS, Gunardi H, Barth PG, et al. The spectrum of cranial ultrasound and magnetic resonance imaging abnormalities in congenital cytomegalovirus infection. *Neuropediatrics.* 2004;35:113–119.
40. Manara R, Balao L, Baracchini C, et al. Brain magnetic resonance findings in symptomatic congenital cytomegalovirus infection. *Pediatr Radiol.* 2011;41:962–970.
41. Kimberlin DW, Jester PM, Sánchez PJ, et al.; National Institute of Allergy and Infectious Diseases Collaborative Antiviral Study Group. Valganciclovir for symptomatic congenital cytomegalovirus disease. *N Engl J Med.* 2015;372:933–943.
42. Luck S, Sharland M, Griffiths P, et al. Advances in the antiviral therapy of herpes virus infection in children. *Expert Rev Anti Infect Ther.* 2006;4:1005–1020.
43. Mareri A, Lasorella S, Iapadre G, et al. Anti-viral therapy for congenital cytomegalovirus infection: pharmacokinetics, efficacy and side effects. *J Matern Fetal Neonatal Med.* 2016;29:1657–1664.
44. Oliver SE, Cloud GA, Sánchez PJ, et al.; National Institute of Allergy, Infectious Diseases Collaborative Antiviral Study Group. Neurodevelopmental outcomes following ganciclovir therapy in symptomatic congenital cytomegalovirus infections involving the central nervous system. *J Clin Virol.* 2009;46(suppl 4):S22–S26.
45. Dahle AJ, Fowler KB, Wright JD, et al. Longitudinal investigation of hearing disorders in children with congenital cytomegalovirus. *J Am Acad Audiol.* 2000;11:283–290.
46. Rivera LB, Boppana SB, Fowler KB, et al. Predictors of hearing loss in children with symptomatic congenital cytomegalovirus infection. *Pediatrics.* 2002;110:762–767.
47. Bilavsky E, Shahar-Nissan K, Pardo J, et al. Hearing outcome of infants with congenital cytomegalovirus and hearing impairment. *Arch Dis Child.* 2016;101:433–438.
48. Amir J, Attias J, Pardo J. Treatment of late-onset hearing loss in infants with congenital cytomegalovirus infection. *Clin Pediatr (Phila).* 2014;53:444–448.
49. del Rosal T, Baquero-Artigao F, Blázquez D, et al. Treatment of symptomatic congenital cytomegalovirus infection beyond the neonatal period. *J Clin Virol.* 2012;55:72–74.
50. Kimberlin DW, Acosta EP, Sánchez PJ, et al.; National Institute of Allergy and Infectious Diseases Collaborative Antiviral Study Group. Pharmacokinetic and pharmacodynamic assessment of oral valganciclovir in the treatment of symptomatic congenital cytomegalovirus disease. *J Infect Dis.* 2008;197:836–845.
51. Gwee A, Curtis N, Connell TG, et al. Ganciclovir for the treatment of congenital cytomegalovirus: what are the side effects? *Pediatr Infect Dis J.* 2014;33:115.
52. Valcyte Safety Data. Available at https://www.gene.com/download/pdf/valcyte_prescribing.pdf. Accessed 13 March 2017.
53. Tomicic MT, Bey E, Wutzler P, et al. Comparative analysis of DNA breakage, chromosomal aberrations and apoptosis induced by the anti-herpes purine nucleoside analogues aciclovir, ganciclovir and penciclovir. *Mutat Res.* 2002;505:1–11.
54. Scott JC, Partovi N, Ensom MH. Ganciclovir in solid organ transplant recipients: is there a role for clinical pharmacokinetic monitoring? *Ther Drug Monit.* 2004;26:68–77.
55. Davis A, Bamford J, Wilson I, et al. A critical review of the role of neonatal hearing screening in the detection of congenital hearing impairment. *Health Technol Assess.* 1997;1:i–iv, 1.
56. Ganitt S, Dionne F, Kozak FK, et al. Cost-effectiveness of universal and targeted newborn screening for congenital cytomegalovirus infection. *JAMA Pediatr.* 2016;170:1173–1180.
57. Williams EJ, Gray J, Luck S, Atkinson C, Embleton ND, Kadambari S et al. First estimates of the potential cost and cost saving of protecting childhood hearing from damage caused by congenital CMV infection. *Arch Dis Child Fetal Neonatal Ed* 2015; 100(6):F501–F506.