Chronic granulomatous disease in pediatric patients: 25 years of experience

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ABSTRACT

Introduction: Chronic granulomatous disease (CGD) is an uncommon primary immune deficiency (affecting 1/200,000 newborn infants) caused by a defect in phagocyte production of oxygen metabolites, and resulting in bacterial infections produced by catalase-positive microorganisms and fungal diseases that occasionally may prove fatal.

Methods: A review is made of the clinical records of 13 pediatric patients diagnosed with CGD between 1980 and 2005.

Results: All patients were males. The mean age at diagnosis was 36 months. The clinical manifestations at the time of diagnosis comprised the following: Abscesses or abscessified adenopathies 4/13 (*Staphylococcus aureus (2)*, *Serratia liquefaciens, S. marcescens* and *Klebsiella sp.*), pneumonia 3/13 (*Rhodococcus equi*, *Salmonella typhimurium* plus *Pneumocystis jiroveci*), osteomyelitis 1/13 (*Aspergillus sp.*), sepsis 1/13 (*S. aureus*), urinary infection 1/13 (*Klebsiella sp.*), severe gastroenteritis 1/13, oral aphthae 1/13 and Crohn-like inflammatory bowel disease 1/13. The diagnosis was initially established by the nitroblue tetrazolium test, and confirmed by flow cytometry 10/13 and genetic techniques (gp91) 9/13. In the course of these disease processes there were 88 infections: abscesses (n = 26), lymphadenitis (n = 12), pneumoniae (n = 10), gastroenteritis (n = 7), sepsis (n = 6), osteomyelitis (n = 3) and others (n = 24). As to the germs isolated, the frequency distribution was as follows (n = 49): *Aspergillus sp.* (n = 10), *Staphylococcus sp.* (n = 7), *Salmonella sp.* (n = 6), *Serratia sp.* (n = 5), *Pseudomonas aeruginosa* (n = 4), *Klebsiella sp.* (n = 4), *Proteus sp.* (n = 3), *Leishmania sp.* (n = 2) and others (n = 8). IFN-γ was administered in 7/13 cases, and itraconazole in 9/13; all received cotrimoxazole. There were four deaths, with one case each of sepsis due to gramnegative bacterial infection; disseminated aspergillosis; visceral leishmaniasis and hemophagocytosis; and post-kidney transplant complications.

Conclusions: Clinical suspicion and flow cytometry are the keys for diagnosis of CGD and detection of carrier relatives. Specific prophylactic measures and medical controls are required to prevent serious infections. IFN-γ has been used intermittently, though its effectiveness is controversial.

Key words: Chronic granulomatous disease. Flow cytometry. Gamma-interferon. Antibiotic prophylaxis. Pediatrics.

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INTRODUCTION

Chronic granulomatous disease (CGD) is an uncommon primary immune deficiency (affecting 1/200,000 to 1/250,000 newborn infants) caused by a defect in phagocyte (neutrophils, monocytes, macrophages, etc.) bactericidal and fungicidal activity. These cells are unable to eliminate the phagocytosed microorganisms[1-3]. At molecular level, the disease is caused by different mutations of the gene that encodes for the enzyme dinucleotide phosphate oxidase (NADPH oxidase), in charge of regulating free oxygen radical production (superoxide anions, hydrogen peroxide, hydroxyl radical) for the destruction of phagocytosed microorganisms.

The NADPH oxidase system in turn is composed of different subunits. The $gp91^{phox}$ and $p22^{phox}$ subunits are located in the cell membrane, forming cytochrome b558 while the other two subunits, $p47^{phox}$ and $p67^{phox}$, are located in the cytoplasm. The gene encoding for gp91 is found in the X chromosome, and its mutations are inherited in a recessive manner. The other genes are located in autosomes, and their mutations show a recessive autosomal hereditary pattern[4-6].

The disease is very often diagnosed in the first years of life of the patient. While there is great clinical heterogeneity among patients with CGD, most develop bacterial infections particularly produced by catalase-positive microorganisms, and fungal diseases. Such infections are severe and recurrent, and often involve the formation of granulomas. The most common clinical manifestations are lymphadenitis, pneumonia and hepatosplenomegalia[5,7].

The laboratory diagnosis of CGD is based on the demonstration of absence of phagocyte oxidizing activity. Many different diagnostic tests have been developed to this effect (direct measurement of superoxide production, ferrocytochrome reduction, the nitroblue tetrazolium test (NBT), and the oxidation test via flow cytometry)[8-10]. Flow cytometry is presently the most widely used technique, due to its greater objectiveness and reproducibility. The treatment options primarily aim to deal with the intercurrent infections and prevent the latter through antibiotic prophylaxis – particularly involving drugs capable of penetrating phagocytic cells (trimethoprim-sulphamethoxazole)[11] and antifungals (itraconazole)[12]. Gamma-interferon (IFN-γ) as a nonspecific stimulant of phagocytic cells is used by many centers for treating the more severe infections[13-15]. Hematopoietic cell progenitors transplants presently offer the only possibility of healing the disease, by replacing the patient immune response cells with normal cells[16,19]. However, MHC compatibility with the donor is required (the latter preferentially being a sibling unaffected by the disease), since the host T cell response is normal. Furthermore, the immune suppressive treatment required to avoid graft versus host disease (GVHD) increases the risk of infections. In future, gene therapy, involving replacement of the mutant gene with the normal gene, may prove to be the most effective treatment option[20-22].

The present study describes the clinical characteristics, the infections detected, and the microorganisms involved in a group of pediatric patients diagnosed with CGD in the period 1980-2005.

MATERIAL AND METHODS

The study data were obtained by reviewing the clinical records of the patients diagnosed of chronic granulomatous disease (CGD) during childhood (age 0-16 years) in the period between January 1980 and December 2005, in Vall d'Hebron University Hospital in Barcelona (Spain). One of the patients was diagnosed and is subjected to control in Sabadell Hospital (Spain).

The study comprised a total of 13 patients, with collection of the following data at diagnosis: age, clinical manifestations, implicated microorganism (in the event of an infectious process), and methods used to confirm the suspected diagnosis.

In most cases, the diagnosis was confirmed using the flow cytometry oxidative test with dihydrorhodamine (9/13 cases, since 1995), while the first cases were diagnosed with the nitroblue tetrazolium test (NBT). Since the first description of the mutant genes implicated in CGD, familial genetic studies are made for diagnostic confirmation, the study of carriers (X-linked forms), and for genetic counseling in the context of prenatal diagnosis, where applicable. The mutational studies were made in the Department of Blood Cell Research in Amsterdam (Dr. D. Roos), in the Division of Immunology of the Kinderspital in Zurich (Dr. J.P. Hossle), and recently in the Immunology Laboratory of La Paz Hospital in Madrid (Spain) (Dr. A. Ferreira).

The flow cytometry oxidative test is based on detection of the fluorescence generated by dihydrorhodamine 123 (DHR) upon activation by the NADPH oxidative system of the previously activated phagocytic cells (or non-activated cells, used as negative controls). Such fluorescence can be detected and measured by the flow cytometer, and is compared between the non-stimulated cells and the stimulated cells – yielding an index for measuring the production of these metabolites[8].

Regarding the treatment provided, we documented the use of prophylactic antibiotic treatment with cotri-

moxazole and/or itraconazole, or the administration at some time of gamma-interferon by subcutaneous route.

A review was also made of all the infectious processes experienced by the patients in the course of the disease, together with the microorganisms involved. Finally, the life course of CGD was examined in each case.

RESULTS

The sample characteristics are summarized in Table 1.

Data were collected on 13 patients (all males) diagnosed of CGD in childhood.

Median age at the time of diagnosis was three years (range 3-137 months). Forty-five percent of the cases were diagnosed before three years of age, and over 90 % before 6 years of age. In one case the diagnosis was established at 12 years of age.

The cases diagnosed before 1995 (10/13) were initially identified by the nitroblue tetrazolium test (NBT). All but four of these cases, and those diagnosed posteriorly, were confirmed by means of the flow cytometry oxidative test (10/13) and using genetic techniques (gp91^{phox}, X-linked transmission) in 9/13. A carrier assessment was made of the female relatives using flow cytometry (fig. 1), together with genetic study in those cases where the mutation was known. All mothers of the patients are heterozygous carriers of the mutation, and an additional four carriers have been identified in two of the families studied. One mother with the mutation (patient 9) presented lesions compatible with cutaneous lupus erythematosus.

The clinical manifestations at the time of diagnosis were: abscesses and/or abscessified adenopathies in four cases, yielding as causal microorganisms *S. aureus* (n = 2), *S. liquefaciens, S. marcescens* and *Klebsiella sp.*; and pneumonia in three cases – with the isolation in two of them of *R. equi*, and *S. typhimurium* (the latter as coinfection with *P. jiroveci*). The other patients initially manifested with different disorders such as osteomyelitis due to *Aspergillus sp.*, urinary infection produced by *Klebsiella sp.*, sepsis due to *S. aureus*, Crohn-like inflammatory bowel disease, severe acute gastroenteritis, and oral aphthae, without isolation of the causal microorganisms in these last cases.

During the course of follow-up, the patients suffered a total of 88 infectious processes (0.27 episodes per patient and year): abscesses (n = 26), lymphadenitis (n = 12), pneumoniae (n = 10), gastroenteritis (n = 7), sepsis (n = 6), osteomyelitis, acute otitis, urinary infection and muguet (n = 3 every one), tonsillitis, typhoid fever and fever syndrome (n = 2 every one) and bacterial conjunctivitis, cryptytis, orchitis, pustulosis and infected subcutaneous granuloms (n = 1 every one) (table 1) (fig. 2).

Causal microorganisms were isolated in 43 of these 88 infectious episodes (49 %), with a total of 49 isolates: *Aspergillus sp.* (n = 10), *Staphylococcus sp.* (n = 7), *Salmonella sp.* (n = 6), *Serratia sp.* (n = 5) *Pseudomonas aeruginosa* (n = 4), *Klebsiella sp.* (n = 4), *Proteus sp.* (n = 3), *Leishmania sp.* (n = 2) and others (n = 8) (fig. 3).

In relation to antibiotic prophylaxis, three patients received only cotrimoxazole (CTMX), while 10 received both antibiotics. Seven patients received IFN-γ at some time during the course of the disease; all of them also received antibiotic prophylaxis with CTMX and itraconazole.

At the end of the study, four patients had died: three due to infection (1 case of sepsis due to an unidentified gramnegative bacillus, one case of disseminated aspergillosis, and one case of visceral leishmaniasis with associated hemophagocytic syndrome), and one due to post-kidney transplant complications. The median patient age at the time of death was 18 years (range 26-240 months).

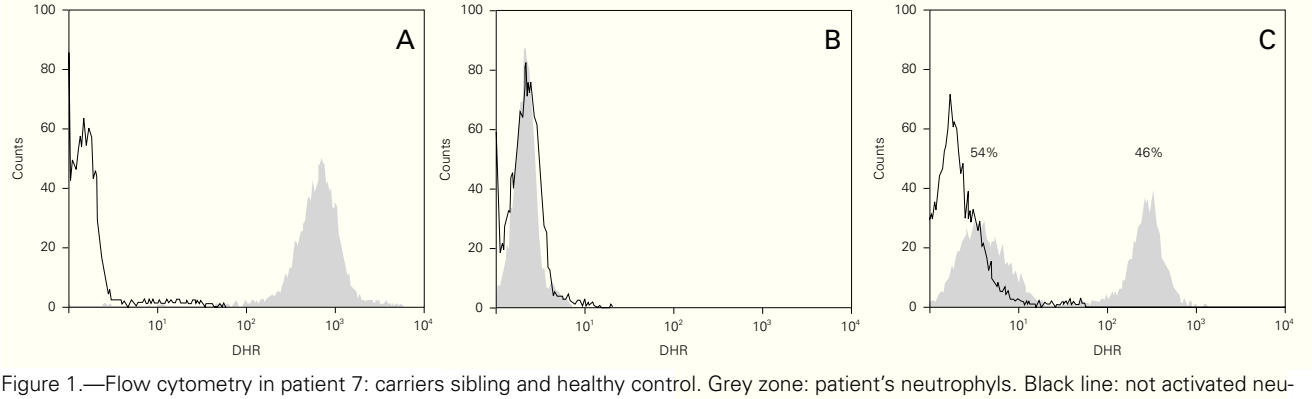

Figure 1.—Flow cytometry in patient 7: carriers sibling and healthy control. Grey zone: patient's neutrophyls. Black line: not activated neutrophyls of control people. A. Normal study. B. Absence of oxidative capacity (diagnose of GCD). C. Two population of neutrophyls with different oxidative capacity (carrier of X-link)

Table 1

Description of the study sample

	Age Dx*	Age at control	Clinic at onset	Microorganism involved	Diagnosing Test
1	3	41	Severe gastrointestinal infection	Not known	OT-FCM
2	5	104	Abscessified adenopathies	*Serratia liquefaciens*	OT-FCM
3	8	207+	Urinary infection	*Klebsiella pneumoniae* y *Klebsiella oxitoca*	NBT
4	11	26+	Sepsis/retroauricular eczema	*Staphylococcus aureus*	NBT
5	17	289	Perianal abscess	*Klebsiella* sp.	OT-FCM
6	37	184	Repeat aphtae + brother with CGD	Not known	OT-FCM
7	48	180	Necrotizing bilateral pneumonia	*Rhodococcus equi*	OT-FCM
8	48	240+	Bilateral pneumonia + sepsis	*Salmonella typhimurium* + *Pneumocystis jiroveci*	NBT
9	49	56	Bilateral pneumonia	Not known	OT-FCM
10	64	220+	Hepatic abscess	*Staphylococcus aureus*	OT-FCM
11	137	304	Osteomyelitis	*Aspergillus* sp.	OT-FCM
12	36	124	Colitis (Crohn like)	–	OT-FCM
13	6	184	Inguinal and laterocervical abscess	*Serratia marcescens* + *Staphylococcus aureus*	OT-FCM

*Age in month.

ITZ: Itraconazole; CMX: Cotrimoxazole; OT-FCM: Oxidative test-Flow cytometry.

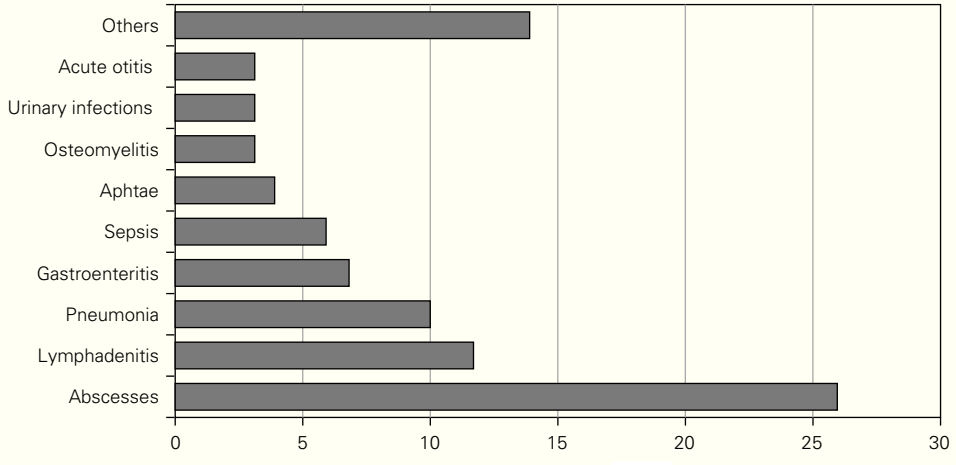

Figure 2.—Infectious processes documented since diagnosis in the patients studied.

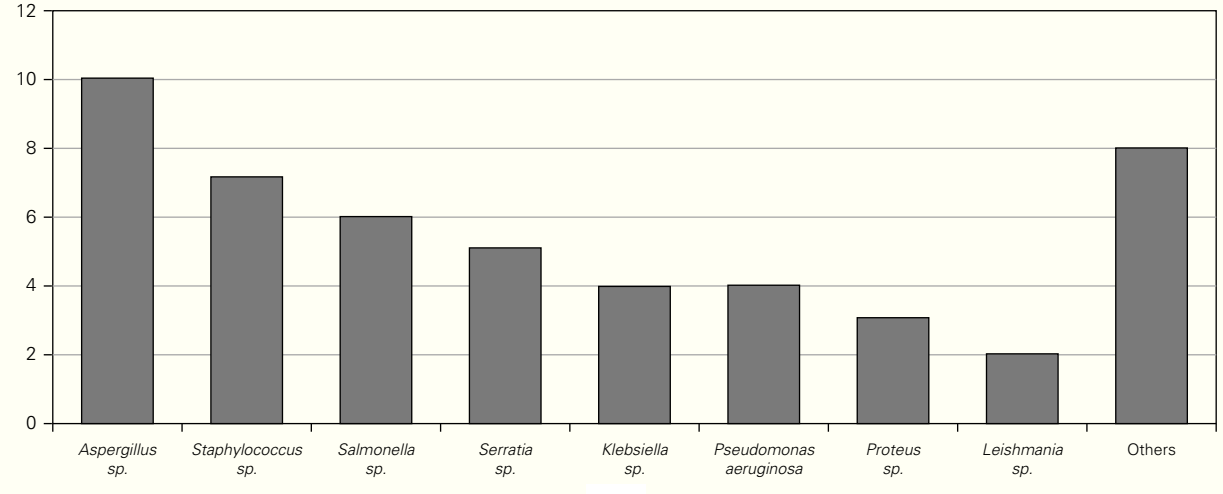

Figure 3.—Microorganisms isolated in the infectious processes cited in figure 2.

Genotype	ITZ	CMX	IFN-γ	Number of Infections	Death cause
X-Link (gp91)	Yes	Yes	No	5	–
X-Link (gp91)	Yes	Yes	Yes	4	–
Not studied	Yes	Yes	No	12	*Aspegillosis diseminata*
X-Link	No	Yes	No	10	Sepsis by not known Gram (–)
X-Link	No	Yes	No	11	–
X-Link (gp91)	Yes	Yes	Yes	2	–
X-Link (gp91)	Yes	No	Yes	4	–
Not studied	Yes	Yes	No	6	Post-renal transplantation complications
X-Link (gp91)	Yes	Yes	Yes	4	–
X-Link (gp91)	No	Yes	No	8	Visceral Leishmaniasis and pneumonia
X-Link (gp91)	Yes	Yes	Yes	6	–
X-Link (gp91)	Yes	Yes	Yes	5	–
X-Link (gp91)	Yes	Yes	Yes	5	–

DISCUSSION

Chronic granulomatous disease (CGD) is a primary immune deficiency resulting from a genetic defect in phagocyte oxidative activity, and gives rise to slow-evolving granulomas and encapsulated infections. Due to the low prevalence of CGD in the general population and the variable severity of the clinical manifestations, the diagnosis of the disease is sometimes established late – a fact that can lead to sequelae that prove difficult to resolve (fig. 4). Diagnostic suspicion in the case of a child with the described clinical manifestations (frequent pneumonia, slowly resolving skin abscesses, adenitis with spontaneous fistulization or inflammatory bowel disease with granulomas) and usually presenting leukocytosis and hyper-gammaglobulinemia, should lead to perform the adequate studies to either discard or confirm the diagnosis of CGD. In this case, antibiotic prophylaxis and the adoption of hygiene-sanitary measures to avoid new infections are essential considerations in order to modify the patient prognosis.

CGD is generally diagnosed in childhood, since the X-linked form of the disease (XL) is the most common and also the most serious presentation of the disorder. Some patients – mainly those presenting an autosomal recessive (AR) form of the disease – can be diagnosed in adult life[23]. In our series, almost one-half of the patients were diagnosed before three years of age, and over 90 % of all cases were identified before 6 years of age. Only one patient was identified at 12 years of age, though in this case there were also compatible clinical manifestations of infection since early infancy. The above may be explained by the fact that all of our subjects presented an XL form of the disease – in coincidence with larger reviews made in other geographical settings[3].

Although the nitroblue tetrazolium test (NBT) is the most readily available diagnostic method, since 1994-1995 the standard technique has been flow cytometry oxidative test. The use of flow cytometry to determine phagocyte oxidative capacity allows more sensitive and reproducible detection of affected patients and carriers, and can indicate the nature of the underlying molecular defect[24]. In our series, flow cytometry oxidative test was used in 10 of the 13 patients. The other three patients were studied before 1995, which is the year in which the flow cytometric method was introduced in our center, and posterior

Figure 4.—Scarring corresponding to abscessified adenitis in patient 9.

oxidative test proved impossible for different reasons.

The absence of phagocytic oxidative capacity in patients with CGD makes them vulnerable to bacterial and fungal infections in different locations. In any case, the increased susceptibility to infection is quite limited to a concrete range of microorganisms – a fact that should contribute to suspect the diagnosis[3]. In our series, the most common clinical manifestations at the time of diagnosis were abscessified granulomata in soft tissues (4/13 cases) and lung involvement in the form of pneumonia (3/13 cases). These results coincide with those of other larger reviews in which pneumonia and adenitis, and skin abscesses, were found to be the main manifestations at diagnosis. Regarding the implicated microorganisms, our observations likewise coincide with the descriptions in the literature, with a predominant presence of *S. aureus*, *S. typhimurium*, *Serratia sp.* and *Aspergillus sp*. This distribution of infections and implicated microorganisms persists throughout the evolution of the disease, with a tendency over time to increase the incidence of cutaneous abscesses and the implication of *Aspergillus sp*. The data obtained in our series coincide with those of larger reviews, where pneumonias were observed in 80 % of the patients, and adenitis and skin abscesses in 50 %. In turn, *Aspergillus sp.* and *S. aureus* were the most common causal microorganisms[3].

It should be noted that one mother (a heterozygous carrier of the mutation) presented lesions compatible with cutaneous lupus erythematosus – a circumstance that has been reported before in the reviewed literature[25,26].

The usefulness of trimethoprim-sulphamethoxazole (CTMX) as antimicrobial prophylaxis in patients with CGD has been well established since the early 1990s, when a significant reduction was achieved in bacterial infections in these patients (both XL and AR forms)[11]. All of our patients received such treatment from the time of diagnosis. However, the demonstration that preventive treatment with CTMX does not modify the incidence of fungal processes led to the evaluation of itraconazole as prevention against *Aspergillus sp*. disease. In 2003, Gallin et al.[12] conducted a double blind study comparing itraconazole versus placebo, in which the former was seen to reduce the incidence of *Aspergillus sp*. in pediatric patients with CGD[12]. Nevertheless, it must be stressed that no statistically significant differences were observed (possibly due to the limited number of patients involved), and that monitorization of the potential side effects (mainly skin rash and transaminase elevations) is required. In our series, 10/13 patients received prophylactic treatment with this antifungal drug, resulting in no side effects requiring treatment suspension.

The effectiveness of IFN-γ is subject to debate, since the exact mechanism by which it acts is not known, and the subcutaneous route of administration involved makes it more difficult to use in children. However, any mechanism capable of boosting activation of some of the other bactericidal mechanisms of phagocytic cells may be of help in eliminating intracellular infections – the latter being the most frequent processes in CGD. Studies in animals have been unable to demonstrate that IFN-γ action takes place through an increase in the oxidative capacity of macrophages[27,28]. However, there appears to be an increased production of mRNA encoding for $p47^{phox}$ – though it is not clear whether this is able to account for the observed reduction in infectious processes in these patients [29]. In turn, a number of studies have suggested clinical benefit with this drug in the case of serious infections in patients with CGD[30-31]. We start therapy with IFN-γ in all patients, together with antibacterial and antifungal prophylactic measures, at the time of diagnosis. Posteriorly, and in the event of a good clinical course, such medication is suspended and reintroduced in cases presenting severe intracellular infections (*Aspergillus sp.*, *R. equi*, etc).

Global mortality in our study was close to 30 %, which is higher than the figure reported in the largest series published to date[3]. In any case, the fact that all of our patients presented X-linked forms of the disease could constitute a source of bias in this sense, since mortality appears to be greater and occurs earlier in this subgroup of patients[3].

In conclusion, it should be stressed that high clinical suspicion and flow cytometry are the keys to the diagnosis of CGD and detection of carrier relatives. In turn, it is important to establish specific antibacterial and antifungal prophylaxis, together with medical controls and the adoption of hygiene-sanitary measures to prevent severe infections. Lastly, while IFN-γ has been used intermittently in our series, its effectiveness in patients of this kind remains controversial.

REFERENCES

1. Notarangelo L, Casanova JL, Conley ME, Chapel H, Fischer A, Puck J et al. Primary immunodeficiency diseases: an update from the international panel of Immunological Societies Primary Immunodeficiency Diseases Classification Committee Meeting in Budapest 2005. J Allergy Clin Immunol 2006;117: 883-896.
2. Kamani NR, Infante AJ. Chronic granulomatous disease and other disorders of neutrophil function. Clin Rev Allergy Immunol 2000;19:141-156.

3. Winkelstein JA, Marino MC, Johnston Jr RB, Curnutte J, Gallin JI, Malech HI et al. Chronic Granulomatous Disease: report on a national registry of 368 patients. Medicine (Baltimore) 2000;79:155-169.
4. Roos D, de Boer M, Kuribayashi F, Meischl C, Weening RS, Segal AW et al. Mutations in the X-linked and autosomal recessive forms of chronic granulomatous disease. Blood 1996; 87:1663-1681.
5. Heyworth PG, Cross AR, Curnutte JT. Chronic Granulomatous Disease. Curr Opin Immunol 2003;15:578-584.
6. Meischl C, Roos D. The molecular basis of Chronic Granulomatous Disease. Springer Semin Immunopathol 1998;19: 417-34.
7. Johnston RB. Clinical aspects of Chronic Granulomatous Disease. Curr Opin Hematol 2001;8:17-22.
8. Emmendorffer A, Nakamura M, Rothe G, Spiekermann K, Lohmann-Matthes ML, Roessler J. Evaluation of flow cytometric methods for diagnosis of chronic granulomatous disease variants under routine laboratory conditions. Cytometry 1994;18:147-55
9. Lun A, Schmitt M, Renz H. Phagocytosis and oxidative burst: reference values for flow cytometric assays independent of age. Clin Chem 2000;46:1836-9.
10. Atkinson TP, Bonitatibus TM, Berkow RL. Chronic granulomatous disease in two children with recurrent infections: family studies using dihydrorhodamine-based flow cytometry. J Pediatr 1997;130:488-91.
11. Margolis DM, Melnick DA, Alling DW, Gallin JI. Trimehoprim-sulfamethoxazole prophylaxis in the management of chronic granulomatous disease. J Infect Dis 1990;162: 723-6.
12. Gallin JI, Alling DW, Malech HI, Wesley R, Koziol D, Marciano B et al. Itraconazole to prevent fungal infections in Chronic Granulomatous Disease. N Engl J Med 2003;348:2416-2422.
13. Marciano BE, Wesley R, De Carlo ES, Anderson VL, Barnhart La, Darnell D et al. Long-Term Interferon-g Therapy for Patients with Chronic Granulomatous Disease. Clin Infect Dis 2004;39:692-9.
14. Nunoi H, Ishibashi F, Mizukami T, Hidaka F. Clinical evaluation of interferon-gamma treatment to chronic granulomatous disease patients with splice site mutations. Jpn J Infect Dis 2004; 57:S25-6.
15. Horwitz ME, Barrett AJ, Brown MR, Carter, et al. Treatment of CGD with nonmyeloablative conditioning and T-cell-depleted allograft. N Engl J Med 2001:344:881-8.
16. Goldblatt D. Current treatment options for chronic granulomatous disease. Expert Opin Pharmacother 2002;3:857-863.
17. Seger R, Gungor T, Belohradsky BH, Blanche S, Bodigoni P, Di Bartolomeo P et al. Treatment of CGD with myeloablative conditioning and an unmodified allograft: a survey of the European experience, 1985-2000. Blood 2002;100:4344-50.
18. Leung T, Chik K, Shing M, Yuen P. Bone marrow transplantation for chronic granulomatous disease: long-term follow up and review of the literature. Bone Marrow Transplant 1999; 24:567-70.
19. Del Giudice I, Iori AP, Megarelli A, Testi AM, Romano A, Cerreti R et al. Allogenic stem cell transplant from HLA-identical sibling for chronic granulomatous disease and review of the literature. Ann Hematol 2003;82:189-92.
20. Chinen J, Puck JM. Perspectives of gene therapy for primary immunodeficiencies. Curr Opin Allergy Clin Immunol 2004;4: 523-7.
21. Puck JM, Malech HL. Gene therapy for immune disorders: good news tempered by bad news. J Allergy Clin Immunol 2006;117:748-752.
22. Ott MG, Schmidt M, Schwarzwaelder K, Stein S, Siler U, Koehl U, Glimm H et al. Correction of X-linked chronic granulomatous disease by gene therapy, augmented by insertional activation of MDS1-EVI1, PRDM16 or SETBP1. Nat Med 2006;12:401-9.
23. Ramanuja S, Wolf KM, Sadat MA, Mahoney SJ, Dinauer MC, Nelson RP Jr. Newly diagnosed chronic granulomatous disease in a 53-year-old woman with Crohn disease. Ann Allergy Asthma Immunol 2005;95:204-9.
24. Crockard AD, Thompson JM, Boyd NA, Haughton DJ, Mc Cluskey DR, Turner CP. Diagnosis and carrier detection of chronic granulomatous disease in five families by flow cytometry. Int Arch Allergy Immunol 1997;114:144-152.
25. Rupec RA, Petropoulou T, Belohradsky BH, Walchner M, Liese JG, Plewing G et al. Lupus erythematosus tumidus and chronic discoid lupus erythematosus in carriers of X-linked chronic granulomatous disease. Eur J Dermatol 2000;10:184-9.
26. Cordoba-Guijarro S, Feal C, Dauden E, Fraga J, García-Díez A. Lupus erythematosus-like lesions in a carrier of X-linked chronic granulomatous disease. J Eur Acad Dermatol Venereol 2000;14:409-11.
27. Jackson SH, Miller GF, Segal BH, Mardiney M 3rd, Domachowske JB, Gallin JI, Holland SM. IFN-gamma is effective in reducing infections in the mouse model of chronic granulomatous disease (CGD). J Interferon Cytokine Res 2001;21:567-73.
28. Condino-Neto A, Newburger PE. Interferon-gamma improves splicing efficiency of CYBB gene transcripts in an interferon-responsive variant of chronic granulomatous disease due to a splice site consensus region mutation. Blood 2000;95:3548-54.
29. Weening RS, de Klein A, de Boer M, Roos D. Effect of interferon-gamma, in vitro and in vivo, on mRNA levels of phagocyte oxidase components. J Leukoc Biol 1996;60:716-720.
30. Conte D, Fraquelli M, Capsoni F, Giacca M, Zentilin L, Bardella MT. Effectiveness of IFN-gamma for liver abscesses in chronic granulomatous disease. J Interferon Cytokine Res 1999;19: 705-710.
31. Touza Rey F, Martínez Vazquez C, Alonso Alonso J, Mendez Pineiro MJ, Rubianes Gonzalez M, Crespo Casal M. The clinical response to interferon-gamma in a patient with chronic granulomatous disease and brain abscesses due to *Aspergillus fumigatus*. An Med Interna 2000;17:86-87.