Case Report
Long-Term Benefits in Lung Function and Nutritional Status of Strict Metabolic Control of Cystic Fibrosis-Related Diabetes

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A B S T R A C T

Cystic fibrosis related diabetes (CFRD) is a strong determinant for lung function decline and increased mortality. Insulin treatment of CFRD is reportedly beneficial for this situation. We report on the long-term impact of insulin treatment of CFRD on pulmonary function and nutritional status in a CF male patient since diagnosis of diabetes.

We report the case of a patient diagnosed with CF at the age of 16. Two years later, he experienced a rapidly evolving decrease in pulmonary function, some months later criteria were met warranting lung transplantation. Concomitantly, he was diagnosed with CFRD and insulin therapy was started. Lung function (spirometry), nutritional status (body mass index) and metabolic control (HbA1c) were determined every 3 months. After the introduction of insulin treatment, pulmonary function and nutritional status progressively improved and good glycemic control was achieved. The significant and sustained improvement in pulmonary function allowed for the patient’s withdrawal from the lung transplantation program within 4 months, a situation which has been maintained until now, 8 years later.

The long follow-up of our patient documents the rapid and prolonged beneficial effect of proper metabolic control of CFRD on the respiratory deterioration in CF.

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Efecto beneficioso y prolongado del buen control metabólico de la diabetes relacionada con fibrosis quística sobre la función pulmonar y el estado nutricional

R E S U M E N

La diabetes relacionada con la fibrosis quística (DRFQ) es un factor determinante del empeoramiento de la función pulmonar y del incremento de mortalidad. El tratamiento con insulina mejora esta situación.

Se presenta el caso de un paciente diagnosticado de fibrosis quística (FQ) a los 16 años. Al cabo de dos años presentó un deterioro rápido de la función pulmonar, cumpliendo meses después criterios de trasplante pulmonar; concomitantemente, fue diagnosticado de DRFQ e inició insulinoterapia. En el seguimiento se evaluaron la función pulmonar por espirometría, el estado nutricional (índice de masa corporal) y el control metabólico (HbA1c) cada 3 meses. Tras iniciar insulinoterapia, obtuvo un buen control metabólico y mejora progresiva espirométrica y del estado nutricional. A los 4 meses ya no cumplía criterios de trasplante pulmonar, situación que se mantiene a los 8 años.

El largo seguimiento documenta un efecto beneficioso rápido y prolongado del buen control metabólico de la DRFQ sobre el deterioro respiratorio en FQ.

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Introduction

Lung function alterations are the main factors responsible for the high mortality of patients with cystic fibrosis (CF). In recent decades, the specialized treatment of CF has significantly increased their life expectancy, and the current average survival is more than 30 years. Lung transplantation is the only therapy available in the final stages of this lung disease. With the increased survival in CF,
more and more patients have the possibility of developing extra-
monary complications. CF-related diabetes (CFRD) is the most
frequent comorbidity and constitutes at the same time a marker for
poorer prognosis and greater mortality.\textsuperscript{3,4} The prevalence of CFRD
increases with age\textsuperscript{5,6} and its appearance is usually preceded by
moderate alterations in the metabolism of carbohydrates, while
there are reports of worsened lung function and nutritional state
years before its diagnosis.\textsuperscript{7,2} The treatment of CFRD with insulin
seems to improve the respiratory and nutritional states of these
patients.\textsuperscript{8,10,11} There are few studies about the duration of this ben-
eficial effect. In patients with CF who require lung transplantation,
the prevalence of CFRD is 28.6%.\textsuperscript{12} We present the beneficial and
prolonged effect of insulin therapy on lung function and on nutri-
tional state in a male with CF who started with insulin at the time
of his diagnosis with CFRD, coinciding with the indication of lung
transplantation.

\section*{Patient and Methods}

\subsection*{Clinical Notes}

A male patient was diagnosed with CF at the age of 16 due
to repeated bronchopulmonary infections and two pathological
sweat tests (95 and 86 mequiv./l chloride ion). Since this age, he
has presented chronic bronchopulmonary infection by \textit{Staphylo-
coccus aureus} sensitive to mexitilin and \textit{Pseudomonas aeruginosa}
sensitive to ciprofloxacin, aminoglycosides, sodium colistimethate
and the majority of antipseudomonal beta-lactams. High resolu-
tion computed axial tomography showed the presence of diffuse
bronchiectasis, predominantly in the upper lobes. At the time
of CF diagnosis, he had a forced vital capacity (FVC) of 4600 ml
(106\%) and a forced expiratory volume in one second (FEV\textsubscript{1}) of
3600 ml (101\%). One year later, the patient was diagnosed with
allergic bronchopulmonary aspergillosis (ABPA) and was treated
with oral corticosteroids for 6 months with maintenance azithromycin
(500 mg administered 3 times a week), with resolution
of the ABPA flare-up. The third year after CF diagnosis, lung
function and nutritional state worsened drastically. The patient
presented numerous pulmonary exacerbations that required sev-
eral cycles of oral and intravenous antibiotics, with a response that
became poorer and poorer and the functional deterioration became
indispensable. In the end, the patient required home oxy-
gen therapy. In an attempt at controlling the lung inflammation
and slowing down the respiratory deterioration, he also received
moderate doses of oral corticosteroids (16 mg/day of methylpred-
nisolone). At the age of 19, he was sent to the lung transplantation
unit at our center due to the rapidly progressing respiratory dete-
rioration, with an FEV\textsubscript{1} of 30\% predicted value and the need for
continuous oxygen therapy; at that time he was being treated
with 20 mg/48 h of methylprednisolone (0.2 mg/kg/day). As part
of the initial transplantation study protocol, the hydrocarbonated
metabolism was evaluated by means of oral glucose overload,
which showed evidence of the existence of CFRD.\textsuperscript{13} He presented
no cardinal symptoms nor did he have a family history of diabetes.
Treatment was initiated with insulin at multiple doses after receiv-
ing diabetes education. Exocrine pancreatic function was always
conserved, with no required substitutive therapy.

\subsection*{Methods}

\section*{Lung Function}

Lung function was evaluated by forced spirometry every
3–4 months, expressing FVC and FEV\textsubscript{1} as percentage of the pre-
dicted value for age, ethnicity, sex, weight and height. Nutritional
state was estimated with body mass index [BMI = weight
(kg)/height\(^2\) (m)] related with age and sex. The criteria for lung
transplantation used were those defined by Prados et al.\textsuperscript{14}
and Liou et al.\textsuperscript{15}.

\subsection*{CFRD Study and Control}

For the diagnosis of the hydrocarbonated alteration, a fasting
oral glucose overload study (administration of 75 g of glucose)
was performed, using the criteria of the American Diabetes
Association.\textsuperscript{16} CFRD treatment was initiated at multiple doses with
regular insulin (Actrapid\textsuperscript{®}) before breakfast, lunch and dinner,
and NPH insulin (Insulatard\textsuperscript{®}) at lunch and dinner, adjusting the
doses according to the capillary glycemia (before and 2 h after
meals and at nighttime) depending on the servings of carbohy-
drates ingested. For the evaluation of the CFRD control, glycated
hemoglobin (HbA\textsubscript{1c}) was determined every 3 months (HPLC to
normal value, 5.3\% ± 0.3\%).

\subsection*{Molecular Study}

DNA analysis was done with the Elucigene\textsuperscript{TM} CF29 v.2 method
(Tepnel Diagnostics Ltd., Oxfordshire, Great Britain). The Delta 508F
and R553X mutations were identified in compound heterozygosis,
confirmed with direct sequencing of the products of the chain re-
action of the polymerase of the exons corresponding with the CFTR
cystic fibrosis transmembrane conductance regulator) gene.

\section*{Results}

After the start of treatment with insulin, a progressive
improvement was observed in lung function and nutritional state
(Table 1) and within 4 months the patient no longer met the cri-
teria for lung transplantation. The doses of corticosteroids were
gradually reduced, and five months after the start of insulin ther-
apy, corticosteroid treatment was able to be suspended without
the patient presenting any lung exacerbations during their with-
drawal. Home oxygen therapy was also suspended and the spirometry parameters improved to the levels prior to the diag-
nosis of CFRD (Table 1). Ten months later, the patient was able to
do regular exercise.

Four years after the diagnosis of diabetes, the patient had
another flare-up of ABPA and required oral corticosteroid ther-
apy for 18 months (initial doses of 1.2 mg/kg/day and later
0.2 mg/kg/day). As a consequence of the immunosuppression
caused by the steroids, he presented two pulmonary exacerbations,
therefore during this period both the lung function and metabolic
control worsened (Table 1, Fig. 1). Once said processes were

\begin{figure}
\centering
\includegraphics[width=\linewidth]{fig1}
\caption{HbA\textsubscript{1c}, values during follow-up after the diagnosis of diabetes.}
\end{figure}
controlled, all the parameters improved. Since then, the patient has not again needed either antibiotic or corticosteroid treatment.

The control of the diabetes was good from the start of the therapy, with an initial insulin dose of 0.5 U/kg/day and adequate levels of HbA1c (Fig. 1). This control experienced alterations coinciding with the lung exacerbations, and it was necessary to increase the dose of insulin to 0.85–1 U/kg/day. Afterwards, the patient recovered good glycemic control with a mean insulin dose of 0.7 U/kg/day.

Currently, at the age of 27, the patient’s CFRD is controlled with the administration of 3 doses of regular insulin before the 3 main meals, together with 2 doses of delayed-action insulin analog detemir (Levemir®) before breakfast and dinner (total dose 0.7 U/kg/day). The metabolic control is very good (HbA1c 6.5%), presenting no diabetic complications. Eight years after the diagnosis of CFRD, the patient does not meet lung transplantation criteria, maintains an FVC of 2.081 L (43%) and an FEV1 of 1.01 L (47%), does not require oxygen therapy and has a good quality of life.

**Discussion**

Several studies have emphasized the beneficial effect of insulin on lung function in patients with CFRD, ascribed not only to its normoglycemia effect but also to the anabolic effect itself of insulin. The deficit of insulin increases the risk for lung infection, worsens nutritional state and leads to a reduction in intercostal and diaphragmatic muscle mass, all of which are factors that contribute to the declining lung function in CF patients. Therefore, very recently the American Diabetes Association, the American Cystic Fibrosis Foundation and the American Pediatrics Society have published a new Consensus-Guide about the screening and treatment of the hydrocarbonated alterations in CF, with the objective of promoting actions as early as possible in order to protect lung function and the nutritional state of these patients. The Guide indicates that, in patients with CF, screening should be done annually starting at the age of 10 by means of an oral overload of glucose. The most innovative agreement is the early use of insulin, even in CFRD without fasting hyperglycemia. It is also pointed out that the use of insulin can even be very positive in phases prior to hydrocarbonated alteration, before the diagnosis of diabetes. Another position of this Consensus is not to use oral anti-diabetic medication in these patients with CF. Dietetic changes and physical exercise play a secondary role in CFRD, where diet should not be restricted and exercise should be adapted to the possibilities of each patient.

In our patient, the good control of CFRD seems to have played a positive role in the improvement of his lung function. A fact that should be kept in mind in this case is that said benefit meant that he no longer met the criteria for lung transplantation. Over the course of the following eight years and to date, there have been no indications for lung transplantation in this patient, except for a limited period of 6 months in the fourth year after CFRD diagnosis, coinciding with the ABPA and pulmonary exacerbations.

CFRD affects 12–35% of the CF population, and its prevalence increases with age. Lung transplantation is the only therapy for definitively controlling the final stage of the lung disease in CF, although it has high mortality and there are strict criteria for the selection of the candidates. Our patient presented factors that are more often associated with the development of CFRD, such as age, the use of systemic corticosteroid therapy and a genotype at risk (mutations R553X and ∆F508). On the other hand, he had two predictive factors for less severe lung disease: late CF diagnosis and pancreatic exocrine sufficiency (which usually exist in patients with less severe CF mutations and without diabetes). Nevertheless, these factors did not protect him from a rapid deterioration in his lung function. Worsened lung function has been demonstrated months and even years before diagnosis of CFRD, a fact which has been confirmed in all age groups.

Although the ABPA in this patient before the diagnosis of CFRD could be considered a risk factor for the abrupt respiratory deterioration, the good response of the patient to steroid treatment, made evident by the significant decline in the total serum IgE values, makes it unlikely that ABPA is the main cause of the pulmonary deterioration that the patient experienced. The absence of important side effects of corticosteroid therapy, such as myopathy, also leads us to believe that the corticosteroid therapy also was not an important risk factor that would explain the rapid lung deterioration of the patient. Furthermore, oral steroids, due to their powerful anti-inflammatory action, are occasionally used in the advanced stages of this disease in an attempt at stopping the respiratory deterioration, despite their possible side effects, such as increased pulmonary exacerbations and hyperglycemia. On the other hand, in this patient the pulmonary exacerbations responded positively to antibiotics, but the functional deterioration did not. The coincidence in time of the diagnosis of CFRD and the initiation of insulin therapy with the noticeable improvement in lung function make diabetes the main candidate for the causal factor of the severe respiratory function deterioration, and the insulin is the main candidate for the causal factor of the marked and maintained clinical
recovery of the patient. Along these lines, previous studies have demonstrated significant improvements in pulmonary function during treatment with insulin in patients with CF.5,10,11,17 The need to maintain insulin treatment in order to achieve good metabolic control once the pulmonary exacerbations are overcome confirms the diagnosis of diabetes, excluding the corticosteroid treatment as the only cause of the initial hyperglycemia, even more so when the dose of methylprednisolone was low at the moment of the diagnosis of CFRD. Although there are no prospective studies on the duration of the beneficial effect of insulin in CF, the results of the clinical parameters in the evolution of our patient support the idea that, at least in some CF patients, insulin therapy leads to a maintained improvement of the lung disease.20

The genotype–phenotype correlation in CF has been studied for the majority of the clinical characteristics of the disease, and a significant direct correlation has not been found.21,22 Our patient possesses the two most frequent mutations of the CFTR gene associated with diabetes in CF (ΔF508 and R553X). The high prevalence of this genotype in CF goes against a causal relationship with the exceptional evolution that we present here. Furthermore, in an extensive international cohort of 399 patients with CF, the genotypic combination ΔF508/R553X did not correlate with a poor evolution of the lung disease.23 Thus, it is possible that other genes other than CFTR can influence in the pulmonary evolution of patients with CF.23,24

In conclusion, the clinical evolution of our patient supports what has already been reported about the role that insulin and the good metabolic control of CFRD can play in the lung function and nutritional state of these patients. This upholds the need to regularly screen for alterations in the hydrocarbonated metabolism of patients with CF that experience a decline in lung function of unclarified causes, as early treatment of CFRD with insulin can have a positive impact.

References