In Vivo Confocal Microscopy of Fuchs Endothelial Dystrophy Before and After Endothelial Keratoplasty

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Importance: This study reveals significant changes of the anterior cornea in Fuchs endothelial dystrophy that probably affect the visual outcomes of endothelial keratoplasty for the disease.

Objective: To determine whether abnormalities of corneal stromal and subepithelial cells in Fuchs endothelial dystrophy resolve after Descemet stripping endothelial keratoplasty (DSEK).

Design: Prospective observational study of 49 corneas of 42 patients with Fuchs dystrophy before DSEK and during 3 years of postoperative follow-up. None of the preoperative corneas were vascularized or had pronounced subepithelial fibrosis on results of slitlamp examination. Corneas were examined using in vivo confocal microscopy to determine stromal cell density and the presence of abnormal subepithelial cells (presumed fibroblasts).

Setting: The cornea service at Mayo Clinic, Rochester, Minnesota.

Participants: Forty-nine corneas of 42 patients.

Intervention: Descemet stripping endothelial keratoplasty.

Main Outcome Measures: Stromal cell density and presence of subepithelial cells.

Results: Subnormal cell density in the most anterior 10% of the host stroma in Fuchs dystrophy before DSEK (mean [SD], 22 030 [6479] cells/mm³ [n=41]) remained unchanged at 2 (20 433 [4993] cells/mm³ [n=35]; P= .36) and 3 years (20 925 [5433] cells/mm³ [n=23]; P=.99) after DSEK. Abnormal subepithelial cells, which formed reticular networks deep to the basal epithelial cells, were visible in 33 eyes (67%) and remained present at 3 years after DSEK. Mean preoperative central corneal thicknesses when these subepithelial cells were and were not visible were 652 (45) and 668 (56) μm, respectively (P=.75).

Conclusions and Relevance: The reduced cellularity of the anterior stroma in Fuchs dystrophy does not recover 3 years after restoring endothelial function. Abnormal subepithelial cells, presumably fibroblasts, are present in most corneas with Fuchs dystrophy requiring DSEK, even in cases with mild edema and in the absence of clinically obvious preoperative subepithelial fibrosis. Anterior corneal structural abnormalities might be related to visual outcomes after DSEK.

FUCHS ENDOTHELIAL DYSTROPHY (hereinafter referred to as Fuchs dystrophy) is a disease of the corneal endothelium that is characterized by guttæ of the Descemet membrane and progressive corneal edema. In addition, the anterior cornea experiences increased haze, keratocyte depletion, and abnormal innervation in Fuchs dystrophy, and these changes are presumably secondary to chronic edema. If untreated, these corneas will become scarred and vascularized, which may explain why Fuchs originally described the disease as an epithelial dystrophy and others have referred to it as a combined epithelial and endothelial dystrophy.

Anterior corneal changes in Fuchs dystrophy were not of importance to visual outcomes when penetrating keratoplasty was the surgical treatment of choice because the full-thickness host cornea was excised and replaced. Now that endothelial keratoplasty (EK), which retains the entire host cornea except the Descemet membrane and endothelium, has become the transplant procedure of choice for Fuchs dystrophy, knowledge of the corneal pathology might be important for understanding the clinical outcomes of this procedure and possibly for determining the ideal time for sur-
Corneal pathology in vivo can be quantitatively and qualitatively examined using in vivo confocal microscopy, and, although some studies have described changes qualitatively in corneas with Fuchs dystrophy, few studies have performed quantitative analyses or described changes after AF.

The primary goal of this study was to determine whether restoration of endothelial function in corneas with Fuchs dystrophy promoted repair of the anterior cornea. Previous research showed that keratocytes were depleted in the anterior stroma in Fuchs dystrophy; in this study, we hypothesized that restoring endothelial function would stimulate repopulation of anterior stromal cells. We examined corneas with Fuchs dystrophy by using in vivo confocal microscopy and determined stromal cell density before and after Descemet stripping EK (DSEK). We also described qualitative changes in corneal cells and structure before and after DSEK for Fuchs dystrophy.

**METHODS**

**SUBJECTS**

Subjects requiring DSEK for Fuchs dystrophy were recruited from the cornea service at the Mayo Clinic and were enrolled in a prospective observational study. The cohort and eligibility criteria have been previously described. Briefly, all subjects had visually significant central guttae with or without edema, as determined using slitlamp biomicroscopy, but subjects were excluded if they had evidence of corneal changes unrelated to Fuchs dystrophy, if the corneas were vascularized, or if they had pronounced subepithelial fibrosis. All eyes were pseudophakic owing to previous small-incision cataract surgery (phacoemulsification) or had lenticular changes requiring cataract extraction.

This study was approved prospectively by the institutional review board, Mayo Clinic, Rochester, Minnesota. Informed consent was obtained from all subjects after discussion of the risks of the study.

**SURGICAL PROCEDURES**

Descemet-stripping endothelial keratoplasty was performed under general or local anesthesia as described previously. In all cases, the donor tissue was prepared with a mechanical microkeratome (ALTK; Moria) and was inserted in the anterior chamber through a 3- to 6-mm scleral tunnel incision. Phacoemulsification and intracocular lens insertion were performed through the same incision before stripping the Descemet membrane in cases that combined DSEK with cataract surgery.

**IN VIVO CONFOCAL MICROSCOPY**

Eyes were examined with a slit-scanning confocal microscope (ConfoScan 4; Nidek Technologies) before and at 1, 2, and 3 years after DSEK. The central cornea was examined by using a through-focusing technique, with a z-ring adapter to stabilize the cornea and provide accurate depth information. Briefly, topical anesthetic (proparacaine hydrochloride, 0.5%) was instilled in the eye, and the objective (original magnification ×40) was coupled to the cornea through the optical medium hydroxypropyl methylcellulose, 0.3% (GenTeal Gel; Novartis Ophthalmics). Two to 4 confocal scans of the central cornea were acquired at each examination by using a step distance of 4 μm and 2 passes per scan. The microscope had been calibrated for depth and lateral resolution as described previously. Each confocal scan was reviewed by one experienced observer (S.V.P.), and the images that corresponded to the epithelial surface, anterior and posterior boundaries of the stroma (in preoperative corneas), surgical interface (in postoperative corneas), and endothelium were identified. Abnormal features at any depth of the cornea were also recorded, including the presence or absence of subepithelial cells, which were presumed to be fibroblasts.

**STROMAL CELL DENSITY**

Stromal cell density was determined in 5 layers of host stroma (most anterior 10%, 11%-33%, 34%-66%, 67%-90%, and most posterior 10%) and 2 layers of donor stroma (anterior and posterior 50%). Density in each layer consisted of the mean density of 2 images from each layer. In the most anterior 10% layer, 1 of the 2 images was always the most anterior image with discernible keratocytes, similar to previous studies, and density for this image was reported in addition to mean density for the most anterior 10% of the stroma. All selected images were first analyzed by an automated program designed to estimate keratocyte density in normal corneas and corneas after refractive surgery. Because the pathological changes in Fuchs dystrophy reduced the accuracy of the automated program for identifying cell nuclei, every image analyzed by the automated program was manually reexamined and corrected by one experienced observer (S.V.P.) in a randomized and masked manner. To facilitate the discrimination of cell nuclei from noise, especially in the anterior hazy cornea, the observer viewed consecutive images adjacent to the image being counted. In contrast to noise, cell nuclei were visible through several consecutive images because the depth of field of the confocal microscope was approximately 26 μm and the frame-to-frame step distance was 4 μm.

Before DSEK, stromal cells were distributed in a larger-than-normal volume of tissue because of stromal edema, resulting in decreased cell density. We considered this swelling when comparing preoperative with postoperative cell densities by adjusting preoperative densities for stromal edema and assuming uniform swelling. Adjusted preoperative density was the product of the measured preoperative density and the ratio of preoperative to postoperative (nondenematous) host stromal thickness at 1 year (39 eyes) or 2 years (2 eyes). We measured stromal thickness by using in vivo confocal microscopy and calculated the distance between the most anterior keratocytes and the most posterior keratocytes (preoperative) or surgical interface (postoperative).

**STATISTICAL ANALYSIS**

The primary outcome was the difference in anterior stromal cell density before and 2 years after DSEK. Assuming a standard deviation of anterior stromal cell density of 5300 cells/mm³, a priori analysis indicated that a minimal difference in anterior stromal cell density of 3700 cells/mm³ (equivalent to an anticipated change of 13%) could be detected with a sample of 30 eyes (α = .05/3, where 3 is the number of comparisons; β = .20 [paired analysis]). Although the primary outcome was assessed at 2 years when all possible data were available, data were analyzed for many eyes at 3 years also.

We compared variables using generalized estimating equation models to account for possible correlation between fellow eyes of the same subject. Variables that were nonparametric were assessed by applying generalized estimating equation models to a rank transformation of the data. We adjusted P values for multiple comparisons using the Bonferroni method, and P ≤ .05 was considered statistically significant. For post hoc
analyses, minimal detectable differences were calculated for non-
significant comparisons ($\alpha = .05/n$, where $n$ was the number of
comparisons; $\beta = .20$). The magnitude of the correlation be-
tween stromal cell density and preoperative central corneal thick-
ness, measured by using an ultrasonic pachometer (DGH 1000;
DGH Technologies, Inc), was illustrated by the Pearson cor-
relation coefficient, and the significance of the correlation was
determined by using generalized estimating equation models.

RESULTS

SUBJECTS

Forty-nine eyes of 42 subjects with Fuchs dystrophy were
enrolled in the study; mean (SD) recipient age was 67
(10) (range, 41-87) years. By 12 months, 2 subjects (2
eyes) had withdrawn from the study, 1 subject (1 eye)
had died, 1 graft had failed, and 1 subject (1 eye) did not
attend for examination, leaving 44 eyes (in 37 subjects)
available for analysis. By 24 months, 6 subjects (6 eyes)
had withdrawn from the study, 1 subject (1 eye) had died,
2 grafts had failed, and 3 subjects (3 eyes) did not at-
tend for examination, leaving 37 eyes (in 32 subjects)
available for analysis. By 36 months, 10 subjects (10 eyes)
had withdrawn from the study, 1 subject (1 eye) had died,
2 grafts had failed, 3 subjects (3 eyes) did not attend for
examination, and 7 eyes (7 subjects) had not yet reached
the 36-month examination, leaving 26 eyes (in 23 sub-
jects) available for analysis.

Preoperatively, confocal data were available for 47 eyes.
A quantitative analysis was possible in only 41 eyes owing
to significant ocular movement (1 eye) or indiscern-
cible opacities (3 eyes) or because a lack of postopera-
tive confocal data to determine true host stromal thickness
prevented the adjustment of preoperative density for stro-
mal edema (2 eyes). At 12, 24, and 36 months, confocal
data were available for 39, 35, and 23 eyes, respectively.

QUALITATIVE CONFOCAL OBSERVATIONS

In Fuchs dystrophy before DSEK, the most striking
changes in the cornea, aside from guttae, were in the an-
terior stromal, subepithelial, and basal epithelial re-
gions (Figure 1). The basal epithelial cells were easily
visible in all eyes, with increased reflectivity of the cell
borders (Figure 1). In 23 eyes (49%), a layer of subepi-
thelial cells, presumably fibroblasts, was visible, often
forming a brightly reflective reticular network (Figure 1).
These cells typically had bright oval nuclei that were mor-
phologically distinct from normal keratocyte nuclei and
were located just deep to the basal epithelial cells at the
level of subbasal nerves. The Bowman layer was also
brightly reflective in most eyes, merging the increased
reflectivity from the basal epithelial and anterior stro-
mal layers. Anterior stromal cells were visibly sparse in
38 eyes (81%) compared with that typical of normal cor-
neas (Figure 1). The morphology of the cell nuclei var-
ed considerably from normal to brightly reflective and
fragmented, possibly representing degenerating cells or
cell remnants (Figure 1). When the cells were sparse, the
surrounding extracellular matrix was typically brightly
reflective (Figure 1).

The midstromal and posterior stromal cells appeared
normal in 38 eyes (81%), but in 9 eyes (19%) they were
abnormal with visible cell bodies (Figure 2). In 6 cor-
neas (13%), multiple punctate (2-3 µm), brightly reflec-
tive opacities were visible throughout the stroma and in
variable density (Figure 2). All corneas had visible gut-
tae, and endothelial cells were visible in 38 corneas (81%);
the endothelial cells were typically large and pleomor-
phic (Figure 2). Descemet membrane exhibited a hon-
eycomb appearance in 2 corneas (4%), and linear “fi-
ers” within the membrane were noted in oblique sections
in 3 corneas (Figure 2). The true frequency of these fi-
ers could not be determined because oblique sections
were not obtained in all corneas.

After DSEK, the basal epithelial cells remained vis-
ible but were less reflective compared with before
DSEK. The subepithelial cells were visible in 16 eyes
(41%) at 12 months, 18 eyes (51%) at 24 months, and 8
eyes (35%) at 36 months (Figure 3). Subepithelial cells
were visible in 33 of the 49 eyes (67%) in at least 1
examination during the 3-year study. Anterior stromal
cells were visibly sparse in 15 eyes (38%) at 12 months,
20 eyes (57%) at 24 months, and 11 eyes (48%) at 36
months (Figure 3). The middle and posterior stromal
cells had normal morphology in all eyes at 12 months,
and, although the stromal punctate opacities were

Figure 1. In vivo confocal microscopic images of anterior corneal pathology
in Fuchs endothelial dystrophy before endothelial keratoplasty demonstrate
various changes contributing to increased anterior reflectivity (haze). A, The
basal epithelial cells were easily visible in all corneas, with brighter than
normal cell borders. C and E, Brightly reflective reticular networks of cells,
variably subepithelial fibroblasts, were often visible deep in the basal
epithelium; occasionally, the nuclei of these cells were visible and appeared
sparse, brightly reflective, and distinct from keratocyte nuclei (Figure 3). B and D, The most
anterior discernable stromal cell nuclei in Fuchs dystrophy were frequently
sparse, brightly reflective, fragmented, and associated with increased
background (extracellular matrix) reflectivity. F, The most anterior stromal
cells of a normal cornea in a 65-year-old patient show the normal
morphology and high density of nuclei in this region. All images represent
areas with dimensions of 428 × 325 μm.
Corneas with Fuchs dystrophy manifest significant anterior corneal abnormalities, even if the anterior cornea appears uncompromised on results of slitlamp examination, and restoring endothelial function promotes minimal repair of the anterior cornea at 3 years afterEK. The depletion of anterior stromal cells and presence of abnormal subepithelial cells might contribute to increased anterior haze and increased anterior corneal aberrations, which are known to affect vision after EK.3,10,11

Fuchs dystrophy is well characterized by posterior corneal guttae and progressive corneal edema, but this study also found anterior stromal cell loss and the presence of abnormal subepithelial cells despite the unaffected appearance of the anterior cornea during the clinical examination. Although advanced cases of Fuchs dystrophy and other causes of chronic corneal edema are associated with significant anterior corneal pathology, such as neovascularization and visible scarring,6,9 none of the cases in this study had neovascularization or pronounced subepithelial fibrosis on slitlamp examination findings. Furthermore, because EK has enabled earlier surgical intervention compared with penetrating keratoplasty, many of the corneas in this study were at an earlier stage in the course of Fuchs dystrophy than those typically examined after penetrating keratoplasty.9 The lack of relationships between anterior corneal abnormalities and preoperative corneal thickness in this study also suggests that the anterior changes might appear earlier in the course of disease than is assumed to be typical.2

Anterior stromal cell density in Fuchs dystrophy was markedly lower than in normal corneas9 and cannot be explained by age-related physiological cell loss.21 This reduced anterior cell density in Fuchs dystrophy has been confirmed by histologic findings,4 and the present study
found that anterior cell repopulation did not occur during the 3-year follow-up after restoring endothelial function. In normal eyes, cell density is highest in a thin anterior layer of the stroma and lower and more uniform in the remainder of the stroma\textsuperscript{19,21}; the anterior cells have been suggested to be a subpopulation of stromal cells with a specific function.\textsuperscript{25-27} Although the exact function of the anterior stromal cells is unknown, they are known to maintain the architecture of the anterior stroma, which is important for maintaining a regular anterior corneal surface\textsuperscript{28} and presumably for maintaining transparency.\textsuperscript{29} Thus, anterior cell depletion might contribute to

Figure 3. Anterior corneal and interface pathology after Descemet stripping endothelial keratoplasty (DSEK) for Fuchs endothelial dystrophy. Subepithelial cells, presumably fibroblasts (A, C, and E), and the most anterior stromal cells (B, D, and F) are shown at 12 (A and B), 24 (C and D), and 36 (E and F) months after endothelial keratoplasty for Fuchs dystrophy. The subepithelial cells persisted through 3 years in some eyes. The appearance of this cell layer varied from distinct oval cell nuclei (A and B) to a reticular network of cell processes (C through F) and was not specific to any postoperative time. The most anterior stromal cells remained sparse and background reflectivity remained increased through 3 years compared with normal cells, contributing to anterior corneal haze. The DSEK surgical interface was easily identified in most eyes by small bright reflections (interface particles) and few cells. The interface images are of the same eye at 12 (G) and 36 (H) months after DSEK and demonstrate an improvement in background reflectivity with time after surgery. All images represent areas with dimensions of 428 × 325 µm.
an irregular anterior surface or increased anterior haze, both of which affect vision in Fuchs dystrophy.3,10,31

Abnormal subepithelial cells, presumably fibroblasts, were observed in most corneas, and these cells were still visible at 3 years after EK. With in vivo confocal microscopy, Mustonen et al13 found fibrous septae in the basal and subepithelial regions in Fuchs dystrophy; with improvements in confocal imaging, the morphologic characteristics and location of this subepithelial fibrosis have become better defined.15,30 We found that subepithelial cells were easily distinguished from stromal cells by their morphology and by their location between the Bowman layer and the basal epithelium, which corresponds to the location of subepithelial fibroblasts.7,9 The origin of subepithelial cells could be keratocytes migrating through normal channels in the Bowman layer, which remains intact until later in the course of Fuchs dystrophy,7 and the trend toward decreased anterior stromal cell density when subepithelial cells were visible might support this possibility. Nevertheless, this trend was not statistically significant and might be explained by the large variability of cell density. Thus, other mechanisms of fibroblast formation and anterior stromal cell depletion should not be disregarded.4,31,32 We did not find a relationship between the visibility of subepithelial cells and preoperative corneal thickness, indicating that these cells could be present in cases with mild edema or early in the disease course.

The anterior changes in Fuchs dystrophy are important because they persisted at 3 years after EK, and they might help explain visual outcomes after EK. After EK for Fuchs dystrophy, increased anterior corneal backscatter (or haze) has been associated with increased disability glare,3,11 and increased anterior corneal aberrations have been associated with decreased visual acuity.10,33,34 Anterior corneal backscatter is higher than normal before EK and improves after EK but does not return to normal with resolution of corneal edema.3,35 By confocal examination in this study, we found that anterior haze before EK was caused by increased reflectivity from basal epithelial cell borders, the Bowman layer, the anterior stromal extracellular matrix, and subepithelial cells. After EK, the improvement in haze was largely explained by an improvement in basal epithelial reflectivity, presumably because of resolution of subtle, nonbulbous, epithelial edema, whereas reflectivity from the subepithelial cells, Bowman layer, and anterior stroma did not improve as much. Thus, even after resolution of corneal edema, haze remains higher than normal after EK because of persistent tissue abnormalities that are probably caused by chronic edema from early in the course of disease.2,18 One explanation for increased anterior corneal aberrations after DSEK could be the networks of subepithelial cells that, because of their location between the basal cells and Bowman layer, might cause an irregular anterior corneal surface. Indeed, anterior corneal haze correlates with anterior corneal aberrations,10 both of which could be attributed to the abnormal subepithelial cells. Further studies that better characterize the onset of and relationships between the anterior corneal abnormalities could help determine whether an optimum time exists for intervening in Fuchs dystrophy to achieve the best outcomes.

In the posterior cornea, observations of guttae and the lamellar interface after DSEK using in vivo confocal microscopy have been described previously.13,23,24,36 Of interest was that stromal cell density in the most posterior 10% of the host stroma was also decreased at 2 and 3 years after DSEK. This finding suggests that these cells form a subpopulation that normally interacts with the endothelium or aqueous humor25,27 and that their separation after DSEK impairs this interaction. Examining for similar changes after Descemet membrane endothelial keratoplasty, in which the posterior stromal cells maintain the

<table>
<thead>
<tr>
<th>Layer of Stroma</th>
<th>Before DSEK* (n = 41)</th>
<th>12 mo (n = 39)</th>
<th>24 mo (n = 35)</th>
<th>36 mo (n = 23)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Host, %b</td>
<td>0-10</td>
<td>22 023 (6749)</td>
<td>21 139 (5562)</td>
<td>20 443 (4993)</td>
</tr>
<tr>
<td></td>
<td>11-33</td>
<td>22 485 (5523)</td>
<td>23 270 (3737)</td>
<td>23 599 (3347)</td>
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<tr>
<td></td>
<td>34-66</td>
<td>21 187 (5799)</td>
<td>20 893 (3868)</td>
<td>22 335 (4775)</td>
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<tr>
<td></td>
<td>67-90</td>
<td>20 155 (4694)</td>
<td>20 735 (5165)</td>
<td>21 401 (5086)</td>
</tr>
<tr>
<td></td>
<td>91-100</td>
<td>20 967 (5643)</td>
<td>22 020 (6454)</td>
<td>17 191 (6505)c</td>
</tr>
<tr>
<td>Donor, %e</td>
<td>Anterior 50</td>
<td>17 588 (6295)</td>
<td>15 916 (5889)</td>
<td>18 198 (6825)</td>
</tr>
<tr>
<td></td>
<td>Posterior 50</td>
<td>21 188 (5933)</td>
<td>21 159 (4500)</td>
<td>20 289 (5044)</td>
</tr>
</tbody>
</table>

Abbreviation: DSEK, Descemet stripping endothelial keratoplasty.

*Cell densities before DSEK were adjusted for stromal edema by using the nonedematous stromal thickness after DSEK and assuming uniform swelling to enable direct comparison with postoperative cell densities.

b Postoperative cell density did not differ from that before DSEK in any layer of stroma unless stated; the average minimal detectable difference was approximately 4600 cells/mm² (α = .05/3, where 3 is the number of comparisons; β = .20). Percentages indicate the most anterior to the most posterior portions of the stroma.

c P = .01 vs preoperative measurement.

d P = .04 vs preoperative measurement.

e Donor cell density did not change after DSEK; the average minimal detectable difference was approximately 4400 cells/mm² (α = .05/2, where 2 is the number of comparisons; β = .20).
same anatomical relationship with the endothelium and aqueous humor, will further our understanding of these cellular interactions, although the consequence of this decrease in posterior stromal cells, if any, is unknown. The punctate stromal opacities, which were prominent in some corneas before EK, might correspond to focal lipid accumulations that have been observed by electron microscopy in corneas with Fuchs dystrophy. Thus, we modified the method of stromal cell density measurement in the present study. First, we used a slit-scanning confocal microscope (ConfoScan 4) that provided better image contrast than the rotating disc confocal microscope (Tandem Scanning Corporation) used in a previous study. Second, after automated analysis of confocal images, all analyzed images were examined manually by an experienced observer (S.V.P.) to correct inaccuracies in cell identification. This modified method proved valid because preoperative and postoperative cell densities were very consistent, and the decreased anterior cell density was similar to that found by histologic analysis. In addition, the lower-than-normal estimate of anterior stromal cell density in Fuchs dystrophy could have been lower yet because preoperative density was adjusted for stromal edema in Fuchs dystrophy, however, increased image reflectivity and poor contrast associated with corneal haze render this automated analysis inaccurate, as determined in a previous confocal and histologic study of the same corneas. Thus, we analyzed all stromal cells, which are predominantly keratocytes, but might include other cell types, such as bone marrow–derived cells. Another limitation of this study was that the presence of subepithelial cells might have been underestimated because of the small field of view (0.14 mm²) of the confocal microscope. In summary, the anterior cornea is abnormal in Fuchs dystrophy, even when results of the slitlamp examination suggest a normal appearance, and it remains abnormal 3 years after EK. The mechanisms of this anterior corneal pathology and the relationships between anterior corneal cells in Fuchs dystrophy are yet to be described. Further studies are required to establish the onset of anterior abnormalities in the disease course and to determine their implications with respect to the timing and outcomes of intervention.

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REFERENCES


